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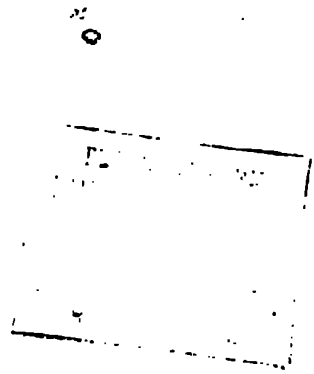

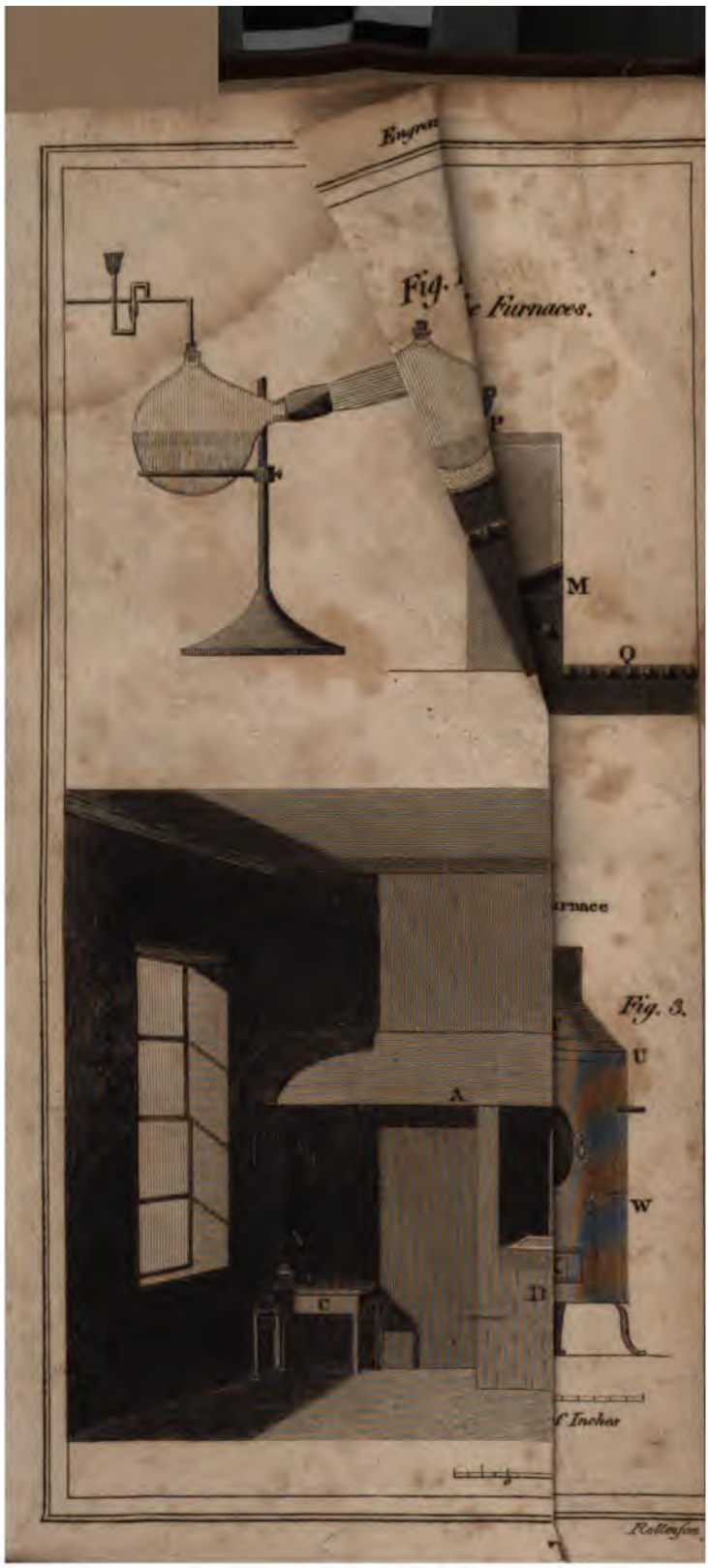
Fig.
Furnaces.
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Rollinson

THE

CHEMICAL CATECHISM,

WITH

NOTES, ILLUSTRATIONS,

AND

EXPERIMENTS.

BY SAMUEL PARKES, F.L.S.

MEMBER OF THE GEOLOGICAL SOCIETY, AUTHOR OF THE RUDIMENTS OF CHEMISTRY,
PROPRIETOR OF THE AQUA-FORTIS WORKS AND CHEMICAL MANUFACTORY
IN GOSWELL-STREET, LONDON.

FROM THE SIXTH ENGLISH EDITION,

WITH EMENDATIONS AND CONSIDERABLE ADDITIONS.

NEW-YORK:

PRINTED AND SOLD BY COLLINS AND CO.

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THE NEW YORK

"Chemical research conducts to the knowledge of philosophical truth, and forms the mind to philosophical enlargement and accuracy of thought, more happily than almost any other species of investigation in which the human intellect can be employed."

TILLOCH.

"Tout homme qui reçoit une éducation libérale, compte aujourd'hui la chimie parmi les objets les plus indispensables de ses études."

FOURCROY.

PREFACE

TO

THE FOURTH EDITION.

THE very flattering reception which "THE CHEMICAL CATECHISM" has met with from the public, three large impressions *having* been sold within a very short period, and the respectable character it has received in the reviews and other periodical publications, have encouraged the author to devote a large portion of his time to the correction and enlargement of the work;—a fourth edition of which he now offers, in a form that he trusts will be approved, and with a confidence that he did not at first allow himself to entertain.

The late highly interesting and truly important discoveries of Davy having thrown new light upon

many branches of chemical science, it became necessary to review every part of the following sheets with great care, that no opportunity might be overlooked of recording the new facts and opinions, in order that the whole of the Text and the Notes might be related to the present state of chemical knowledge.

The author, however, is far from claiming any merit on this account; he conceives that he could never deserve the continuance of that patronage which the public has so liberally bestowed, were he to neglect giving that public a faithful detail of all such discoveries of importance as have transpired since the former editions were prepared for the press.

In the hope of rendering the present impression still more acceptable, a variety of new matter has been added, particularly in the notes; a large portion of the text has been entirely re-written; the collection of *Experiments* has been enlarged; and he has obtained permission to make drawings of the Laboratory at the Surry Institution, which he has had engraved by an eminent artist, on purpose

for the work: and as this elaboratory contains a set of the latest and most approved chemical furnaces of any in the metropolis, the measures have all been accurately taken, and the drawings made to a correct scale, so that any gentleman at a distance from town, might, by inspecting the engraving, be able to direct a workman to erect a similar establishment, either wholly, or in part.

Though the author might now, perhaps, be justified in omitting to state the motives that first induced him to engage in writing a Treatise on Chemistry, it may nevertheless be observed, that, in considering the great *importance of* chemistry to the arts and manufactures, it occurred to him, that an initiatory book, in which simplicity was united with perspicuity, would be an acceptable present to a variety of persons, who have not had leisure or opportunity to study more elaborate works; and especially to those parents who are not qualified by previous acquirements, to instruct their children in the elements of this science, than which there can be nothing more essential, in whatever line of life they may be destined to move. As an attempt, therefore, to supply this desideratum, "The

hment and modification of those lav
ch are so infinitely and beautifully
se operation is too minute to be th
eral notice. For, if it could be pr
sfaction of youth, that matter is s
variety of laws which escape comm
e, and that, in the adjustment of thos
ost attention, if it may be so expr
n paid to our convenience and comf
tail, it was imagined, would tend t
e indelible impression on the you
1 the display of the same goodness i
on of causes which come under our da
observation.

magnificent system of nature; and though such remarks may perhaps be regarded by some as irrelevant to chemical science, yet, to repeat the former apology, it may be observed, that, in compiling any initiatory book, no writer, as a parent, could lose sight of the necessity of embracing every favourable opportunity of infusing such principles into the youthful mind, as might defend it against immorality, irreligion, and scepticism.

For the accommodation of schools, and to render the generality of parents and preceptors more competent to explain and expatiate upon the variety of facts which the science of chemistry presents, and to qualify them *in some measure* to afford such answers to a number of questions, which the young pupil, in proportion as he advances and becomes more interested in the experiments, will not fail to demand, the author has added a variety of explanatory notes. Many of these will be found to contain new matter, or, at least, what is not generally known or published; others, and perhaps the majority, were drawn from various sources; but as many were quoted from memory, and still more from the common-place book of the compiler, he was obliged, in some instances, either to omit

the authorities, or entirely forego the advantages he had derived from the works, experiments, and opinions of some of the most enlightened chemical philosophers of the age. Here, however, he has constantly been guided by one rule—to produce rather what is us ginal.*

It may also be that the catechetical form, which was first n for this work, has been found to possess east all the advantages that any other mode of i ucting youth in chemistry can claim, the work having already been introduced with advantage into several of the most eminent seminaries in the kingdom; and, that, if the author's original intention be followed, the progressive improvement of the student will be pleasant, rapid, and correct.

The author assuredly never expected that the answers should be committed to memory *verbatim*

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* With this view, not only a succinct account of the different branches of chemical knowledge has been given, but he has uniformly endeavoured throughout the work to direct the reader to the best treatises in each department of the science, with a view to facilitate higher attainments, and to render "The Chemical Catechism" a kind of text-book for the student.

by the pupil, nor indeed, that the language of the questions should always be literally adhered to by the tutor; but merely that the whole should be clearly comprehended by the parent or tutor, which, with the assistance of the notes, is no difficult task, and then to allow the student to employ his *own language* to explain his ideas, and form the responses.

Thus, this treatise, it is confidently hoped, possesses every requisite to render it a *first book* for the chemical student; and that, whether it be employed as a catechism, as a set of dialogues, as matter for familiar conversation, or as a book for the closet, still the original design—a correct initiation into the science of chemistry—will be the result; for if these rudiments of chemical knowledge have been drawn in such a form as to invite the young to study larger and more extended works, and to prepare them to adopt that theory only which can be substantiated by their own experiments, the chief intention of the author will then be fully accomplished.

ADVERTISEMENT

THE [illegible]SH EDITION.

The author h[illegible] much time and attention to the improvemen[illegible] the former editions of this work, has no[illegible] l such notes as were necessary to give the reader a knowledge of those discoveries in the science, which have transpired since the last edition was published.

A new plate has also been engraved, as a frontispiece for this impression, which, together with fine paper and careful printing, will, he trusts, render THE CHEMICAL CATECHISM, *in its* Sixth Edition, *still more acceptable to the public.*

January 18, 1814.

DESCRIPTION OF THE PLATE.

THE Laboratory of the Surry Institution, at Black-friars Bridge, London, having been constructed agreeably to the design and under the immediate direction of Mr. Richard Knight of Foster-Lane; the author of this work, conceiving it to be one of the most complete experimental laboratories in the kingdom, obtained permission to make such drawings of the different apparatus as would enable any competent workman to construct a similar establishment. For this purpose the whole is drawn and engraved to a correct scale, which is placed beneath each compartment of the engraving.

The upper part of the plate contains a section of the principal furnaces, in order to show their interior construction; and the lower part represents a front view of the entire arrangement, on a smaller scale.

A A A. Is a hood or covering extending over the whole, and communicating with two air-flues, B B, that pass through the roof of the building, and are terminated by ventilators. These flues convey away any smoke or noxious vapour from the furnaces or other apparatus, without becoming offensive to the operator.

C. A leaden sink, plentifully supplied with water. It has a drain pipe which carries off the waste water beneath the floor.

D. A square sand-bath, heated by a fire-place, the door and register of which are seen, in the shade, on the right.

E E. Two round apertures closed by stoppers, and communicating with a spare flue which is concealed in the wall

of the building. These are intended to receive the iron pipes of such moveable furnaces as may be occasionally employed.

F. Is a furnace containing an iron sand-pot calculated for distillation with a glass or earthen retort, as represented at F. in the section. This furnace is so constructed that the iron pan may be readily removed, and a copper still, an iron retort, or other appa its stead.

G G. A muffle-f ng metals by cupellation, for experiments o nd staining glass, and for the roasting of me

H H. A furnace y the naked fire. In the section H. is placed k of which passes through an opening left in furnace for that purpose, and which is luted up during an operation. This furnace is well contrived for the distillation of phosphorus, quicksilver, oxygen gas, &c.

I I. Iron doors opening on a level with the furnace grates, for the purpose of raking the fire, removing and replacing the bars, &c.

K K. Doors of the ash pits.

L. A smelting or wind furnace for the reduction of metallic ores, and other purposes requiring the highest degrees of heat. Section L. shows the interior of this furnace, with a crucible within it. M. is an aperture for clearing or withdrawing the bars of the grate.

N. A reverberatory, or annealing, furnace. This forms a chamber through which the heated air and flame of the furnace L. pass in their way to the chimney O. This addition is found to improve materially the draught of the furnace L, and is also particularly useful in heating crucibles to a proper temperature preparatory to their being used in that furnace.

P P. Moveable covers suitable for either of the furnaces

G, H, L, or N. These covers are made with fire-bricks ground neatly, and bound together by a strong rim or band of iron. There is a hole in the centre of each, secured by an earthen stopper, which may be opened occasionally to inspect the state of the fire or the progress of the operation.

Q. An extended ash pit, covered by a moveable iron grate. This kind of ash pit very much economizes the room in a laboratory, as it admits a large current of atmospheric air, and allows the operator to stand closer to the furnace.—Throughout the whole of this apparatus, the chimneys are distinct, each furnace having its own; but being carried up within the wall of the building they cannot be described in this plan.

R. *fig.* 5. represents Mr. Knight's table-furnace made of wrought iron, of dimensions according to the scale annexed, the inside of which is lined with a coating of fire clay. S. a door to allow the introduction of a crucible, &c. T. another door in the cover, through which the fuel (charcoal) is to be introduced. U. an opening which serves as a chimney when the top is taken off and a sand pot is to be used; or it will admit the neck of a retort for the purpose of distilling with the naked fire; this opening is also calculated for the introduction of a muffle. X. the door of the ash pit. W W. two apertures, opposite to each other, through which an iron, earthen, or any other tube may be passed, in order to demonstrate the decomposition of water, and for other operations which require such an arrangement.

abstruse sciences: yet by this knowledge he was enabled to invent such mechanical engines as were sufficient to resist the whole Roman army. And such a dread had the soldiers of this man's science, that if a rope only were let down from the walls of the city of Syracuse, the whole army would retire from before it in the utmost consternation.

A further proof of the importance of the dissemination of useful knowledge [illegible] rom the construction of the *Steam Engine.* [illegible] en acknowledged that his first ideas on th[illegible] cquired by his attendance on Dr. Black'[illegible] res, and from the consideration of his th[illegible] at and the expansibility of steam.

The well-inform[illegible] nce are so satisfied of the importance of [illegible] edge, that chemistry is already become an [illegible] part [illegible] ducation in their public schools.—It shall be my business in this place to endeavour to demonstrate it to be of *equal* importance to the various classes of our countrymen, that the science should be cultivated with the same ardour in these kingdoms. The science we here recommend to your regard, has for its objects every substance of the material world, and, therefore, is equally interesting to every civilized nation upon earth.

Is your son born to opulence,—is he the heir to an extensive domain; make him an analytical chemist, and you enable him to appreciate the real value of his estate, and to turn every acre of it to the best account.

Chemistry will teach him also how to improve the *cultivated* parts of his estate; and by transporting and transposing the different soils, how each may be rendered more productive. The analysis of the soils will be followed by that of the waters which rise upon or flow through them; by which means he will discover those proper for irrigation; a practice the value of which is sufficiently known to every good agriculturist.

Should he *occupy* his own estate, and become the cultivator of his own land; he must of necessity be a chemist, before he can be an economical farmer. It will be his concern not only to analyse the soils on the different parts of his farm; but the peat, the marle, the lime, and the other manures must be subjected to experiment, before he can avail himself of the advantages which might be derived from them, or before he can be certain of producing any particular effect. The necessity of analysis to the farmer is evident from a knowledge of the circumstance, that some kind of lime is injurious to land, and would render land hitherto fertile actually steril. Besides, a knowledge of the first principles of chemistry will teach him when to use lime *hot* from the kiln, and when *slaked;* how to promote the putrefactive process in his composts, and at what period to check it, so as to prevent the fertilizing particles becoming effete, and of little value. It will also teach him the difference in the properties of marle, lime, peat, dung, mud, ashes, alkaline salt, soap waste, sea water, &c. &c.; and, consequently, *which to prefer* in all varieties of soil. A knowledge of the chemical properties of bodies will thus give a new character to the agriculturist, and render his employment rational and respectable.*

Are you a practitioner of MEDICINE, and have acquired great and deserved reputation in your profession,—if you are not a chemist, you must recollect many painful disappointments, and must have witnessed very unexpected results from the effects of medicine, when you have administered two or more powerful remedies in conjunction. A slight knowledge of chemistry would have informed you that many of the formulæ in the Pharmacopœia, which are

* Lavoisier cultivated 240 acres of land in La Vendee, on chemical principles, in order to set a good example to the farmers; and his mode of culture was attended with so much success, that he obtained a third more of crop than was procured by the usual method, and in nine years his annual produce was doubled. *Lalande's Life of Lavoisier.*

salutary and efficacious, are rendered totally otherwise if given with certain other medicines,—not to say often destructive. Many instances of these chemical changes might be adduced, but one will suffice. Mercury and oxygenized muriatic acid have both been administered by medical men; and *separately*, either of them may be taken without any injury to the animal economy: but if a physician, ignorant of the chemical op[illegible]es on each other, should give these substa[illegible]*ction*, the most dreadful consequences migh[illegible]he product of this mixture (*oxygenized* [illegible]*ury*) is a most corrosive poison.

If the profession o[illegible] your son's choice, charge him, when he walks [illegible], to pay particular attention to the Lectures on Che[illegible]ry, and to make himself master of the chemical affinities which subsist between the various articles of the Materia Medica. This will inspire him with professional confidence; and he will be as sure of producing any particular chemical effect upon his patient, as he would if he were operating in his own laboratory. Besides, the human body is itself a laboratory, in which, by the varied functions of secretion, absorption, &c. composition and decomposition are perpetually going on: how, therefore, can he expect to understand the animal economy, if he be unacquainted with the effects which certain causes chemically produce? Every inspiration we take, and every pulse that vibrates within us, effects a *chemical* change upon the animal fluids, the nature of which requires the acuteness of a profound chemist to perceive and understand. Neither can a physician comprehend the nature of the animal, vegetable, or mineral poisons without the aid of chemistry.* Many thousand lives have been lost by poison, which might have been saved had the physician been in

* All *animal* and *vegetable* poisons destroy by deoxidizing the blood. Substances which contain a large portion of oxygen are the real antidotes to such poisons. On

possession of the knowledge which he may now acquire by a cultivation of chemical science. And though the operation of many of the poisons upon the system be in these days well understood, nothing but a knowledge of chemistry can enable the practitioner to administer such medicines as will counteract their baneful effects.

If we look to the MANUFACTURES of the kingdom, there is scarcely one of any consequence that does not depend upon chemistry for its establishment, its improvement, or for its successful and beneficial practice. In order to see the connexion which subsists between chemistry and the arts, it will be necessary to take a short view of the principal trades which are carried on in these kingdoms.

One of the staple manufactures of the country is that of IRON: and it will be found that, from the smelting of the ore to the conversion of it into steel, every operation is the effect of chemical affinities. In the first place, it requires no small share of chemical knowledge to be able to appreciate the *value of* the different ores, and to erect such furnaces for their reduction as may be *contrived* in the best possible manner for facilitating their fusion, and for producing good pigs. The subsequent processes to convert the metal into malleable iron are entirely chemical, and will be conducted to the best advantage only by those who have acquired a knowledge of the chemical changes which take place in these operations. The making of CAST-STEEL, which has been kept so profound a secret, is now found to be a simple chemical process, and consists merely in imparting to the metal a portion of carbon, by means of fusing

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the contrary, *metallic* poisons are baneful in consequence of the oxygen they contain. Metals are devoid of activity in a metallic state; but when converted into oxides they become poisonous and corrosive, according to the portion of oxygen combined with them. Thus the gray and the white oxides of mercury are only purgative or alterative; while the red oxide is a corrosive poison. Decoctions of bark, having a great affinity for oxygen, have been given to counteract an over-dose of antimonial powder, and have produced the desired effect.

it in crucibles with carbonate of lime, or by cementation with charcoal powder, in a peculiar kind of furnace constructed for that particular purpose.

The manufacturers of *utensils*, &c. in cast-iron (called IRON-FOUNDERS) will also acquire some valuable information by the study of chemistry; as it will teach them how to mix the different l ; how to apportion the carbonaceous and c er; and how to reduce the *old* metal, which t ive in exchange; many hundred tons of whic sent away as ballast for ships, for want of th ich would enable them to convert it into go n.

The WOOLLEN, the cot he CALICO manufactures are also become of great importa ce to these kingdoms. In order to preserve these sources of national wealth, the utmost attention must be paid to the beauty, the variety, and the durability of their several colours. Now of all the arts, none are more dependent upon chemistry than those of DYEING and CALICO-PRINTING. Every process is chemical; and not a colour can be imparted but in consequence of the affinity which subsists between the cloth and the dye, or the dye and the mordant which is employed as a bond of union between them. It is surely then evident how valuable a chemical education must be to that youth who is designed for either of these trades, and how necessary is that portion of knowledge which shall enable him in a scientific manner to analyse his different materials, and to determine the kind and the quantity necessary for each process. After all, his colours will be liable to vary, if he do not take into the account, and calculate upon, the changes which take place in them by the absorption of oxygen; a knowledge of which, and of the different degrees of oxidizement which the several dyes undergo, requires no small share of chemical skill: and yet this skill is absolutely necessary, to enable either the dyer or the calico-printer to produce in all

cases, permanent colours of the shade, which he intends. Moreover, these artists must be indebted to chemistry for any valuable knowledge which they may acquire of the *nature* of the articles they use in their several processes; not to say that they are wholly dependent upon this science for the artificial production of their most valuable mordants, and for some of their most beautiful and brilliant colours.*

The art of BLEACHING, which is so intimately connected with calico-printing, has also received such improvement from the science of chemistry, that no man is now capable of conducting it to the best advantage, without a knowledge of the principles on which the present practice is established.

The manufactures of EARTHEN-WARE and PORCELAIN, which were so much improved and extended by the ingenious and industrious Wedgwood, and which are become by his means a source of *national wealth*, and give employment to

* An instance or two will render this evident. Formerly a calico-printer required many weeks to produce a printed cotton with some colours, such as an olive ground and yellow figures; a scarlet pattern on a black ground; or a brown ground with orange figures:—but, by means of chemical preparations, the whole of this work may now be done in a few days; patterns, more delicate than ever, may be produced; and all with a degree of certainty of which former manufacturers had no idea; the system being now entirely altered. According to the former practice, the mordant was first applied to those parts of the cloth that were intended to be olive, brown, or black; it was then necessary for the piece to remain some time before it could be dyed, and afterwards to be exposed in a bleaching-ground a sufficient time to clear those places from the colouring matter of the dye which had not been acted upon by the mordant: a different mordant was then applied by the pencil; and it was necessary to pass the whole piece through the dyeing-copper a second time, in order to give the desired colour to those particular parts and finish the pattern.

Now, all these effects are produced by dyeing the cloth a self colour in the first instance, and afterwards merely printing the pattern with a chemical preparation, which discharges a part of the original dye and leaves a new colour in its stead. Thus a brown may be changed in an instant to an orange; a dark olive to a yellow; or a black to a bright scarlet. In consequence of similar improvements, rich chintz patterns, which formerly required two years or more to be completed, are now commonly finished in a few weeks.

s of the community, are dependent upon chemistry
ccessful management of all their branches, from the
of the materials which form the body of the ware,
oduction of those brilliant colours which give a va-
e manufactures by their permanency and beauty.
Vedgwood was so sensible of the importance of
y to these arts, that he not only applied to the
the science himself, but, upon the death of
brated Dr. Lewis (author of the Commercium
hico-Technicum,) actually engaged his assistant
hisolme, to experimentalize with him, and to de-
whole attention to the improvement of the manu-
y the application of his chemical knowledge, of
rhaps few men in the kingdom at that time had a
are. A faint idea of the advantages which he de-

enabled on chemical principles to ascertain the exact quantity necessary for any fixed portion of silex, which to those who are ignorant of our science must always be a matter of uncertainty, and must repeatedly subject them to losses and disappointment.

The TANNING OF HIDES is a process which was formerly carried on by persons who merely followed a routine of operations, to which they had been accustomed, without knowing the real cause of any of the changes produced. It has now, however, been well ascertained, that the whole art consists in impregnating the animal matter with that peculiar principle taken from the vegetable kingdom called *tan*, (or *tannin*,) the effect of which may be explained entirely on chemical principles. It is also now known that many substances, besides oak bark, contain tan; and to chemistry we are indebted for the means of discovering with accuracy the *quantity* of tan which the several astringent vegetables contain. Besides, this principle having been formed *artificially by* a modern chemist, it is not improbable that, whenever these manufactures pay a proper attention to the science we recommend, they may be able to direct us how to prepare for them, in our laboratories, the article in question, so as entirely to supersede the use of oak bark. This would be an event of great national importance, as the demand at present is so great, that it is not only imported from the continent, but trees, it is well known, have been actually cut down on purpose for the bark. Should the chemical tanner not be fortunate enough to make a discovery of the kind just mentioned, he will at least be able to analyse the substances now in use, and to appreciate their *relative* value; a matter of no small moment to a man who operates upon a large scale. Chemistry will enable him also to combine

the tanning principle with the skins, so as to form leather the most impervious to moisture; and to give the hides the greatest increase of weight in the least possible time: —and these are the main secrets on which the profit of the trade chiefly depends.

The manufacturers of MOROCCO LEATHER, an article entirely new in th[illegible]f this country, have the utmost reason to [illegible] of chemical knowledge. Till within these few [illegible]nsumers of morocco depended entirely on a[illegible]y, many fruitless attempts having been made [illegible]e article in this country. Later trials, with [illegible]al mordants, have, however, so far succee[illegible]eral manufactories have been established in th[illegible]is, where the most beautiful moroccos are now prepared at prices which have superseded the necessity of all foreign importation. Notwithstanding this, some colours are still produced by these manufacturers in a tedious and expensive way :—a series of well-conducted and appropriate chemical experiments would no doubt direct them to prepare the same colours, with greater certainty, and by a more economical process.

The manufacture of SOAP, an art of considerable importance, and which materially aids the revenue of the country, has in general been conducted, like many of the foregoing, without any regard to system: and yet, perhaps, there is no manufacture which can be benefited in such various ways by chemistry as this. To those who are designed for this trade I have no hesitation in recommending the study of the science as a matter of the first importance. Many thousands per annum, now lost to the community, would be saved, if the trade were in general carried on upon scientific principles. Make a soap-boiler a good chemist, and you teach him how to analyse barilla, kelp, potass,

&c. so as to ascertain the proportion of alkali in each,—the only sure guide to purchasing with advantage and profit, which with the common manufacturer is mere chance. When these articles are at an exorbitant price, he will have recourse to various residuums, which he will decompose by *chemical* means, and make use of as substitutes. He will learn, in choosing his tallows, how to avoid those which contain a large portion of sebacic acid, which require much *more* barilla than good tallow, and yet produce *less* soap. He will know how to oxidize the common oils and oil dregs, so as to give them consistence, and render them good substitutes for tallow,—and how to apportion his lime so as to make his alkali perfectly caustic, without using an unnecessary quantity of that article. He will be aware of the advantage to be derived from oxidizing the soap while boiling. A knowledge of chemical affinities will teach him how, at a cheap rate, to make as good and as firm soap with *potass*, as with the mineral alkali; and how *to take up* the heterogeneous salts, so as to give the alkali full opportunity of forming a chemical combination with the oils, tallows, &c. And lastly, he will know how to make use of the *waste* lyes so as to decompose the salts which they contain, and convert them to good and serviceable alkali fit for future operations. Manufacturers of soap, in general, avail themselves of none of these advantages.

The manufacture of CANDLES, which is often connected with the foregoing, though it is of comparatively small importance, may yet derive advantages from chemistry, which would repay the study. Foreign tallows, which frequently contain a large portion of acid, rendering them inferior to the English, may be purified at the most insignificant ex-

y chemical means; and by the proper application
ical agents, other brown tallows may be rendered
ly white, and fit for the best purposes.

e great quantities of candles are used, as in large
tories, mines, collieries, &c. a great saving would
n the use of carburetted hydrogen gas, which pro-
beautiful intense light, much more cleanly than oil
, and at little or no expense. A slight knowledge
ode of managing the gases would enable the pro-
f collieries to procure this gas from the small coal,
trodden underfoot, and to light up his coal-pits
with the greatest safety, and at NO EXPENSE. If
le were adopted, the workmen would be lighted
tter than they can possibly be by any other means;
s of pounds would be annually saved to the com-
and the many tons of tallow, which are now con-
n these subterranean works might be used in the

is converted to a *saccharine* substance by malting;* how the fermentative process converts the saccharine to a *spirituous* substance; and how the latter, by a continuation of the process, becomes changed into *vinegar*. The nature of fermentation (which till lately was entirely unknown) will be studied and understood; and they will not only have learnt the means of promoting and encouraging this process, but how to retard and check it, whenever it is likely to be carried too far; so that the scientific brewer will be as sure of uniformly obtaining satisfactory results, as he would if he were operating on matter by mere mechanical means.

In like manner the DISTILLER, the maker of SWEET WINES, and the VINEGAR MANUFACTURER, will all receive benefit from the cultivation of the science we are recommending. Till the promulgation of the new chemical doctrines, the making of vinegar was carried on like many *other trades*, in which the makers themselves had no idea of the nature of their own process. An acquaintance with chemistry will teach them many important matters; particularly how it is that the spirituous fermentation is succeeded by the acetous; and how the liquor acquires the substance necessary to produce this change. When this is once known, they will soon find by experiment how to oxygenise their wash at the least expense, and in the least possible time. Indeed, when chemical knowledge is more advanced, the process which now takes several months will probably be completed in a few days.

The REFINING OF SUGAR is also a [illegible] process: every branch of which depends upon [illegible] known to chemists. The separation of the [illegible] molasses: the absorption of the superabundant acid: the granulation of the purified sugar; and the crystallization of candy: will

* There is a valuable paper on malting in the 4th volume of the Memoirs of the Manchester Society, by Mr. Joseph Collier.

all be conducted most economically, and with the least difficulty, by those who have studied the science with a view to the improvement of their art.

The REFINING OF GOLD AND SILVER may appear to be merely a mechanical operation; but even in this trade the artist cannot produce a single effect which is not attributable to the play of the chemical affinities. Besides, there is great reason to believe that a considerable portion of silver is often lost in the process which succeeds that of *quartation*, by the blue water being removed to the verditer-vats before the whole of the silver has been precipitated. A knowledge of chemical principles would suggest to the refiner a mode by which, without the aid of any apparatus, he might in an instant detect even a tenth of a grain of that metal, if left in the solution.

The manufacturers of ALUM, of COPPERAS, of BLUE VITRIOL, and of all other SALTS, would likewise do well to become chemists, before they attempt to bring their several arts to the perfection of which they are capable. The crystallization of salts depends upon so many adventitious circumstances, that no small share of knowledge is necessary to enable a manufacturer at all times, and in all seasons, to produce the article he intends. Till lately the MAKERS OF ALUM bought alkalies of every description. An accurate analysis of alum has now discovered that potass and ammonia are the only alkalies which enter into the composition of alum; and consequently, that during a long series of years large sums have been expended by the manufacturer for an article of no use.

Even science itself is now reaping the benefit of its own discoveries. A few years ago, the MANUFACTURERS OF PAPER were apprehensive that it would be impossible to supply a quantity of that article fit for printing upon, adequate to the increasing demand. Necessity, however, often the source of new inventions, had recourse to chemistry;

and in this science, of universal application, found the means of improving the colour of the very coarsest materials;—so that rags which formerly would have been thrown by for paper of the lowest description, are now rendered subservient to the progress of truth, and the promulgation of knowledge. And so easy is the application, that an immense quantity of the materials can be prepared in a few hours; and paper sufficient to print a copy of the largest work in the English language may thus be whitened at the expense of only a few pence.

In like manner it might be shown that the making of BREAD, SUGAR, STARCH, VARNISH, and OIL OF VITRIOL, the REFINING OF SALTPETRE, and the MANUFACTURES OF PRUSSIAN BLUE, CUDBEAR, ARCHILL, and other colours, are all dependent upon chemistry for their improvement and successful practice:—but I flatter myself that the examples already adduced are sufficient to show that chemistry *is now a necessary* branch of the education of youth. Even the management of a GARDEN may receive improvement from a cultivation of this science, as it explains the growth of vegetables, shows the use of the different manures, and directs the proper application of them.

The various operations of Nature,* and the changes which take place in the several substances around us, are so much better understood by an attention to the laws of chemistry, that in every walk of life the chemist has a manifest advantage over his illiterate neighbour. And it may be remarked, that in case of failure or disappointment in any particular line of commercial manufacture, the scientific chemist has resources as various as the produc-

* "Man should observe all the workmanship and the particular workings of Nature and meditate which of these may be transferred to the arts."—Lord Bacon's *Advancement of Learning*, book v. 144

tions of the country in which he lives, to which the uneducated man has no access.*

Were parents aware of this truth, that sordid maxim *primò vivere, deindè philosophari*, would not be heard: but every youth would be instructed in the first principles of natural philosophy and chemistry, as *the means* of qualifying him for conducting with advantage the concerns with which he might be intrusted. If "knowledge is power," surely the *love* of knowledge, and a taste for accurate investigation, is the most likely way for conducting to opulence, respectability, and rational enjoyment.

Moreover, it is the necessary consequence of an attention to this science, that it gives the habit of *investigation*, and lays the foundation of an ardent and inquiring mind. If a youth has been taught to receive nothing as true, but what is the result of *experiment*, he will be in little danger of ever being led away by the insidious arts of sophistry, or of having his mind bewildered by fanaticism or superstition. The knowledge of *facts* is what he has been taught to esteem; and no reasoning, however specious, will ever induce him to receive as true what appears incongruous, or, cannot be recommended by demonstration or analogy.

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* A very remarkable instance of a whole nation availing themselves of advantages presented to them by chemistry, in a case of the greatest emergency, may be seen in the Chemical Catechism, Additional Notes, No. 22

CHAPTER I.

INTRODUCTORY AND MISCELLANEOUS.

WHAT is Chemistry?

Chemistry* is the science which enables us to discover the peculiar properties of all natural bodies, either in their simple or compound state.†

The pupil is advised to go through the catechetical part of each chapter before he attends to the notes; for, as the questions generally arise out of the preceding answers, the connexion of the whole will be best perceived, and most likely to be remembered, by this method.

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* The following definitions of chemistry have been given by some of our best writers. That in the text is sufficiently concise to be committed to memory.

"Chemistry is the *study of the effects of heat and mixture*, with the view of discovering their general and subordinate laws, and of improving the useful arts."—Dr. Black's Lect. vol. i. 12.

"Chemistry is that science which treats of those events or changes in natural bodies which are not accompanied by *sensible* motions."—Dr. Thomson, vol. i. 3.

"Chemistry is a science by which we become acquainted with the intimate and reciprocal action of *all* the bodies in nature upon each other."—Fourcroy's General System of Chemical Knowledge.

† The basis of chemical science is the analytical examination of the works of nature, and the investigation of the properties and uses of the several substances with which we are acquainted: it should therefore be the first concern of every chemical student to receive nothing as true but what has actually been proved by experiment or analogy. Let him rely upon nothing but facts, and he will be in little danger of forming extravagant or erroneous opinions. If we "dare to investigate Nature, we must *see* her and *try* her on all sides, and be sure that she still confesses the same thing."

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an has no access.*

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† The basis of chemical science is the analytical examination of the works of nature, and the investigation of the properties and uses of the several substances with which we are surrounded: it should therefore be the object of every general student to receive nothing as true but what has been proved by experiment or analysis. Let him read, think, but doubt, and he will be in little danger of [illegible] or erroneous opinions. "If we wish to [illegible] we must learn to *doubt* for on all sides, and be suspicious of all people see the same thing."

How do chemists examine the properties of bodies?

The chemical examination of bodies is in general effected by producing a change* in the *nature* or *state* of the body under examination.†

By what means do chemists effect a change in the qualities or states of natural bodies?

This is generally effected by means of *heat*,‡ or

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* This change is frequently effected by the addition of some other substance which can form a combination with a part of the substance under examination, and leave the other part in a detached state. On this principle re-agents, or chemical tests, are employed, the operation of which will be explained as we proceed.

† To the eye, many substances appear similar to other substances, though they possess different, and perhaps opposite, qualities; it therefore becomes necessary to discover the means of analysing these substances, and of ascertaining wherein their difference consists. These we find in chemical *re-agents*.

It may, with few exceptions, be considered as an axiom in the science of which we are treating, that *whenever chemical action takes place, a real change is produced in the substance operated upon, and that its identity is destroyed.* An example will place this in a clear point of view. If a little carbonate of lime (powdered chalk) be put into a glass of water, the chalk will sink to the bottom of the vessel. Though it should be mixed with the water, if left at rest it will soon subside. No chemical action has taken place; therefore the water and the carbonate of lime both remain unaltered. But if a small quantity of diluted sulphuric acid be added to a glass of chalk and water, a violent effervescence will commence the moment they come into contact with each other; a chemical union of the two substances will be the consequence of this chemical action; the identity of each substance will be destroyed; and sulphate of lime (a body entirely different from either of the substances employed) will be produced.

‡ Heat has a tendency to separate the particles of all bodies from each other. Hence nothing more is necessary to effect the decomposition of many bodies than to apply heat, and collect the substances which are separated by that means. The mixture of two or more compounds often produce a decomposition in each by means of chemical *affinity*, a property of bodies which will be more fully explained hereafter.

by the *mixture** of some other matter with the matter intended to be examined.†

How does the application of heat and mixture enable chemists to examine the properties of bodies?

By these means we effect the *decomposition* of a compound body, and thus acquire a knowledge of the nature of its ingredients.‡

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* It is owing to the laws of affinity that we are enabled to examine natural bodies by means of *re-agents*, or chemical tests. Some of these are simple, and act by *single* affinity; others, which are compound, act by producing a *double* decomposition. See chap. xiii.

† Some idea of this mode of examination may be given by the following experiment:—Put a small piece of solid camphor into a phial half filled with diluted alcohol; in a short time the camphor will be dissolved in the fluid, and the spirit will be as transparent as at first. This solution is owing to the affinity which subsists between these two substances. If water be now added (which has a greater affinity for the alcohol than the camphor has) the water will unite with the ardent spirit, and the camphor will be precipitated. In this way, the camphor may be nearly all recovered, as at first. By distillation the alcohol may also be separated from the water, and exhibited in a separate state.

‡ This is also called analysis. It is distinguished by chemists into the *simple* and the *complicated* analysis. The former is effected whenever a body is so decomposed that its elements may be exhibited in a separate state, and the body reproduced by reuniting these elements. Where the elements of a body form *new* compounds during its decomposition, and cannot be reunited to reproduce a similar substance to that which has been operated upon, it is an instance of *complicated* analysis.

In order to ascertain the exact nature of bodies, we have often recourse to *synthesis* as well as analysis. Whenever the component parts of any body are reunited in order to form a similar substance, and a similar substance is actually produced, the nature of that body is said to be proved by synthesis. When a body admits of being examined in both these ways, the result is as satisfactory as can be desired.

The examination of those substances which we receive from the hand of Nature, if conducted on these principles, may sometimes be tedious, but the consequences will be pleasing; the

What is meant by decomposition?

In chemical language, decomposition means the art of dividing a body into its simple elements.* Thus water may be decomposed, and reduced into oxygen and hydrogen, which are simple substances, incapable of further decomposition.

What are the d *s of natural bodies?*

All bodies are *lid,*† liquid, or aëriform.

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processes may be slow, *ill be sure*; and the acquisition of truth, by pa *tion,* and by means of our own exertion, affords *d* mind the most delightful gratification.

"Nature, exhaustless still, has power to warm,
And ev'ry change presents a novel charm."

* Take sulphate of magnesia (Epsom salt) as an instance of the decomposition and re-formation of a substance by chemical means. Make a solution of this salt in boiling water, and pour into it a little of a solution of carbonate of soda: the soda will precipitate a white powder, which on examination will be found to be carbonate of magnesia. When settled, decant the supernatant liquor, evaporate it till a pellicle rises on its surface, and set it aside to crystallize. When cold, crystals of sulphate of soda (Glauber's salt) will be found in the vessel. In this decomposition, the sulphuric acid of the Epsom salt combines with the soda to form sulphate of soda, and the carbonic acid of the soda combines with the magnesia to form carbonate of magnesia. Thus Epsom salt may be analysed, and shown to consist of sulphuric acid and magnesia. In order to prove the composition of this salt by *synthesis*, dissolve magnesia in diluted sulphuric acid, saturate the liquor, and crystallize. Epsom salt will be the result.

It may be remarked, that chemists have not only the power of decomposing natural bodies, but of producing, by certain combinations, various other substances, such as are not found in the kingdoms of Nature. Alcohol and ether are both of this class.

† When attraction prevails in bodies, they become solid; when caloric or the matter of heat prevails, they become gas: fluidity seems to be a medium between the two. The ultimate particles of matter existing in these separate states escape the cognizance

What do you mean by a solid body?

Solidity is that quality of bodies whereby their parts cohere firmly,* so as to resist impression.†

What are liquid substances?

Liquid substances are those whose parts do not cohere firmly, but readily yield to any impression, and have free motion among themselves.‡

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of our senses. They are so infinitely small, as not only to evade the scrutiny of the highest magnifying powers in glasses, but even imagination itself is incapable of forming any idea of the size of an original particle of matter. When we have reduced matter to the most impalpable powder, we are far, very far, from the atoms which compose that powder.

A new theory to account for the phænomena of matter has been proposed by the celebrated Boscovich, and admitted by many philosophers. An account of this system may be seen in the Supplement to the Encyclopædia Britannica, under the article *Boscorich*.

* The force of cohesion increases in a substance in proportion as its moleculæ are brought nearer together. Thus alumine, which has *shrunk* considerably in bulk by being submitted to a high degree of heat, has not *only experienced* much mechanical cohesion, but has thereby acquired the power of resisting acids and alkalies. See Berthollet's Chemical Statics, vol. i. 3.

† Sir Isaac Newton has said, that the primary particles of all bodies are *hard*, whether solid or fluid; and that if the particles be so disposed or fitted to each other as to touch in large surfaces, such body will be hard; otherwise it will be soft. Perhaps, it would be more philosophical to say, that when the attraction of aggregation is strong enough to resist the motion of the particles of a body among themselves, that body will be solid, otherwise it will be soft.

Lavoisier has explained solidity thus:—"The particles of all bodies," says he, "may be considered as subject to the action of two opposite powers, repulsion and attraction, between which they remain in equilibrio. So long as the attractive force remains stronger, the body must continue in a state of *solidity*; but if, on the contrary, heat has so far removed these particles from each other as to place them beyond the sphere of attraction, they lose the cohesion they before had with each other, and the body ceases to be solid."

‡ We have no reason to suppose that fluidity is an essential property of any liquid substance whatever: but rather that

What occasions the difference in these bodies?

Liquid substances are nothing more than solids converted into liquids by heat,* a certain increase of which would convert the liquids into vapour.

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solidity is the natural state of all bodies; for we are able to reduce most substances luidity by the combination of caloric. In genera d in this way expand in all their dimensions, and of aggregation is so much weakened thereby, t es of the body slide over each other, and are by the slightest impulse. This is the only disti cter of fluidity that we are acquainted with.

On the contrary, mber of liquid substances take a *solid* form by emperature. Thus water congeals, and forms ice. gases show this disposition. Chlorine, or oxymuriatic comes concrete, and crystallizes at a temperature near to that at which water congeals. All the gaseous substances, when they have lost their elasticity by forming certain combinations, are disposed to assume the solid state, if the temperature allows it. Ammoniacal gas and carbonic acid gas become solid as soon as they enter into combination; and hydrogen gas, the most subtile of the ponderable elastic fluids, and 14 times lighter than the air we breathe, forms, with oxygen gas, the water which becomes ice. See more on this subject in the first volume of Berthollet's Chemical Statics.

* Fluidity is owing to the matter of heat being interposed between the particles of the fluid; which heat would dissipate all fluids into the air, were it not for the pressure of the atmosphere, and the mutual attraction which subsists between those particles. Were it not for this atmospheric pressure, water would not be known in any other states than those of ice and vapour; for, as soon as ice had acquired caloric enough to give it fluidity, it would evaporate, and be dispersed into the regions of space. This may be proved by direct experiment, as will be shown in the following chapter. The constitution of the world in this respect exhibits a beautiful instance of the harmony of nature, and of the exquisite contrivance of its divine Author.

On the other hand, could we totally abstract the matter of heat from any fluid, no doubt but that fluid would by that mean be changed to a solid; the lightest vapours being nothing more than solids combined with heat.

Not only fluids, but all those substances which are soft and ductile, owe these properties to the chemical combination of caloric. Metals owe their malleability and ductility to the

What other name is given to liquids?

They are likewise called fluids: we call the air also a fluid.*

Why is the air called a fluid?

Because it flows like a fluid;† because like a

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same cause; for, in very intense artificial colds, the most ductile metals, such as gold, silver, and lead, lose their malleability and become brittle, as Van Mons has shown, Annales de Chimie, tom. xxix. 300.

The following experiment will *prove* that it is caloric which converts solids to fluids:—Expose a pound of water and a pound of ice, both at 32°, in a room the temperature of which is above the freezing point. The water will arrive at the temperature of the room several hours before the ice is melted. The caloric, therefore, which has all the time been entering into the ice, but is not to be found in it by the thermometer, must have become *chemically* combined with it in order to give it fluidity. The caloric appears to be lost; its properties are merged in the fluid, just as muriatic acid, by union with lime, loses all its characteristic properties. See this further explained in the chapter on caloric.

* *Atmospheric* air is one of the permanently elastic fluids. Steam is an elastic *fluid; but atmospheric* air in all states, and in all seasons, is *permanently* elastic. This elasticity arises from caloric being chemically combined with the solid substances of which it is composed. I say *solid*, because we have abundant evidence that oxygen and nitrogen are both capable of taking a solid form, and actually do, in many instances, exist in a state of solidity. Nitrogen is a component part of all animal substances, and exists in a solid state in all the ammoniacal salts. Oxygen takes the same state when it combines with metals and other combustibles; and in the composition of the nitrous salts they both take the same state of solidity. These facts surely evince that atmospheric air owes its fluidity to caloric.

One of the general laws discovered by Dr. Black, and which he laid down as a chemical axiom, was, that "whenever a body *changes* its state, it either combines with caloric, or separates from caloric." The great number of natural appearances which are explained by this general law renders it important, and it ought to be remembered by all who wish to make a progress in the knowledge of the science.

† The air is also known to be a fluid, by the easy conveyance which it affords to sound.

In chemical laboratories a vacuum is often formed in the retorts and other glass vessels, which occasions explosions, and

another, though their absolute weights be the same.*

How do you explain the difference in the specific gravity of different bodies?

When one body is larger, or takes up more room, than another of the same weight, the first is said to be *specifically* lighter† than the other, and vice versa.

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found that the water in the scale will exactly fill the vacancy left by the wood.

* The specific gravity of bodies is denoted in chemical writings by comparing it with the specific gravity of pure water, in decimal figures, water being always considered as 1.000. Thus the specific gravity of the strongest sulphuric acid of commerce is said to be 1.900, or nine-tenths heavier than water. Iron is 7.650, or more than 7½ times heavier than water; that is, a cubic inch of iron, if put into a scale, would require 7½ inches of water to balance it; silver is 10.473; gold, 19.300; and platinum 23.000, or 23 times heavier than water. The specific gravity of bodies is noted in the same way throughout this work.

† The nations of antiquity were unacquainted with any method of ascertaining the specific gravity of bodies. A singular event was the cause of its being discovered by Archimedes 200 years before Christ. Having reason to believe that an unprincipled goldsmith had greatly debased the golden crown of Hiero II. king of Syracuse, he was anxious to ascertain the fact; but was perplexed by not knowing how to effect it. However, one day while bathing, the difference in the weight of his own body, when in the water and when out of it, gave him the idea that he might adopt *that* method for discovering the specific gravity of the king's crown; and it is related of him that he was so rejoiced at the discovery, that he leaped from the bath in an ecstasy, and ran through the streets of Syracuse, crying *I have found it! I have found it!* It would be a pleasing, and not altogether an unprofitable employment, to endeavour to recount the mathematical, philosophical, and chemical truths, that we are in possession of, which tend to promote the happiness and civilization of man, and which the ancients were unacquainted with. In these enlightened times every youth may find avocations suited to his taste, and even in his pleasures will be at no loss to select amusements which are both rational and respectable.

What definition do you give of the air which you spoke of in connexion with this subject?

The air is that very light fluid which surrounds* us every where; it is the medium in which we live, and without which we could not exist.†

What is the great body of this fluid called?

It is called the atmosphere.‡

You say the atmosphere is fluid; what proof have you of its being so?

Many instances might be adduced to show that the atmosphere is fluid, but the ascension of an air-balloon is a sufficient proof of its fluidity.§

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* If the earth had no atmosphere at the time of its formation, we may easily conceive how an atmosphere might be produced by the decomposition of water and other substances. I refer the reader desirous of investigating this subject, to an interesting essay in the second chapter of Lavoisier's Chemical Elements.

† It may be remarked that the Creator has endowed atmospheric air with the property of preserving its own equilibrium at all times, and in all places. Its elasticity is such, that, however it may be consumed by respiration or combustion, its place is immediately supplied with a new portion; and though by a mistaken policy the doors and windows of our habitations may be constructed so as to exclude it as much as possible, it *will* have admission; it forces its way through every crevice, and performs the important office assigned it, in defiance of all our exertions. If the properties which are given to the different substances in nature, and the laws by which they are governed, be thus examined, we shall find them all tending to one point, viz. the welfare and felicity of every species of animated beings.

‡ This word is derived from the Greek language, and signifies a body of vapour in a spherical form. By this name we understand the "entire mass of air which encircles all parts of the terrestrial globe, which moves with it round the sun, which touches it in all its parts, ascending to the tops of its mountains, penetrating into its cavities, and incessantly floating on its waters. It is the fluid which we inhale from the first to the last moment of our existence."

§ Atmospheric air, like all other elastic fluids, yields to the

do you account for an air-balloon floating
*tmosphere?**
use the whole, when inflated with gas, is
cally lighter than an equal bulk of common

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impulse, and is put in motion with the greatest ease;
s not the power of penetrating many substances, like
some other fluids.
cility and rapidity of the motions of atmospheric air
e explained on any principle but its fluidity. Some of
move nearly at the rate of 4000 feet in a minute.
and the following question may appear to be an
epetition of the doctrine taught in the first part of this
but as innumerable facts dependent on specific gravity
tually occurring in every department of chemistry, it
ght advisable thus to *vary* the questions, in order to
possibility of a young person committing this chapter
ory without thoroughly understanding what is so im-
his future progress.

What is the specific gravity of atmospheric air?

A pint measure of atmospheric air weighs only eight grains; the same measure of pure water weighs one pound, avoirdupois.*

If the specific gravity of water be so much greater than that of atmospheric air, how is water retained in the atmosphere?

The water which is taken up by the atmosphere

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him to comprehend the cause of a variety of effects which will take place during the course of his experiments. When this is understood, it may be proper to point out some of the advantages which we derive from this property of fluids. That, owing to this principle, the oxygen gas which is secreted by vegetables is detained in the *lower* regions of the air, that it may combine with the nitrogen gas produced by animal respiration, to preserve the purity of the atmosphere; that, owing to this, the carbonic acid gas, which is still heavier, and which is formed also by animal respiration and combustion, is confined within the reach of vegetables, which absorb it with avidity, and separate it into its original elements;—and that to this principle it is also attributable that the mephitic air, arising from the crowded haunts of men, does not produce pestilence, but mounts above the clouds to await fresh combinations by means which nature has appointed to render it again useful and salubrious. One great use of *lightning* may perhaps be to promote the union of this nitrogen with the oxygen of the water which is held in solution in atmospheric air. That the Deity has established some way of effecting this is evident, for without some such contrivance the purity of the atmosphere could not be preserved. Winds also may probably promote this union.

"His wisdom guides the rushing wind,
Or tips the bolt with flame:
His goodness breathes in ev'ry breeze,
And warms in ev'ry beam." DARWIN.

* The measure here alluded to is the common wine pint. From this one may deduce a calculation that a cubic foot of atmospheric air weighs nearly one ounce and a quarter; a cubic foot of water 1000 ounces, avoirdupois.

in an aqueous state, but is converted into
* by the matter of heat.†
is it that heat converts water into vapour?
ge portion of the matter of heat combining
ally with water renders it specifically *light-*
ich is the cause of its rising, and mixing
e atmosphere.‡
is effected in any of the great operations of

a great part of the rain which falls upon
h becomes changed at length into vapour,§
es into the air in that state to form clouds.

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of importance to satisfy a young person of the truth
thing we teach him, and whenever it can be done it
to be omitted. By inverting a glass goblet over a

What is the cause of the waters of the earth being thus vaporized?

As the rays of the sun warm the ground,* a portion of the matter of heat combines with a portion of the water of the earth, and converts it into vapour.†

But what causes the vapour to rise in the air?

If a cork be placed at the bottom of a basin of water, it rises immediately to the top, because it is specifically lighter than the water:‡ so vapour

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grass plat, and collecting the vapour which attached itself to the inside of the glass, he found that an acre of ground dispersed into the air above 1600 gallons of water in the space of 12 hours of a summer's day.

The ocean loses many millions of gallons of water hourly by evaporation. The Mediterranean alone is said to lose more by evaporation, than it receives from the Nile, the Tiber, the Rhone, the Po, and all the other rivers that fall into it. This water is conveyed by the winds to every part of the continents:—*these it fertilizes* in the form of rain, and afterwards supplies the rivers, which flow *again into the* sea. This is one of those continual circulations whereby all matter is made to subserve various purposes, which have been devised by the Creator for the promotion of his beneficent designs.

"The bounteous sun
Lifts the light clouds sublime, and spreads them thin,
Fleecy and white o'er all-surrounding heaven."

In our climate evaporation is found to be about four times as much from the vernal to the autumnal equinox, as from the autumnal to the vernal. Heat facilitates all solutions; and the greater the difference between the temperature of the air and the evaporating surface, the greater will be the evaporation.

* In winter, the earth at eighteen inches depth is warmer than the air; in summer, the air is warmer than the earth at that depth: these effects are owing to the earth being a bad conductor of heat.

† The action of the sun upon the earth in producing vapours, &c. is easily explained on chemical principles. Nicholson, or any other modern writer on natural philosophy, may be consulted. The shelter which is afforded to the earth by clouds, mists, &c. is due to the operation of this cause.

‡ I have introduced this and other very familiar examples,

the air, because it is specifically lighter
e air.*

*becomes of the water which thus evaporates
earth?*

cupies the lower regions of the atmosphere,†
preserved there partly dissolved‡ in air,§
tly in the state of elastic vapour.

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think it of consequence that those who have the care
oung people should encourage them to inquire the
very thing which they see around them. A precep-
is well qualified for his employment, will not think
too trivial which can furnish him with an opportunity
ing useful knowledge.

evident that water exists in the atmosphere in abun-
ven in the driest seasons and under the clearest sky.
substances which have the power of absorbing water
air at all times; such as the fixed alkalies, and sul-
id: the latter of which will soon absorb more than its

How is this vapour formed into clouds?

After it has remained some time in the atmosphere, it becomes in a measure condensed by causes unknown to us;* and the particles of water of which it is composed unite, and form small hollow vesicles, which accumulate together† and produce clouds.

From this property of the air we derive many advantages. It has a tendency to preserve every thing on the face of the earth in a proper degree of moisture. In one season of the year, in the interior parts of Africa, a wind prevails called the *Harmattan*, which is so extremely dry that household furniture is destroyed by it; the paunels of wainscots split; boarded floors are laid open; and the scarf skin of the body peals off, during its continuance. Were it not for the property which atmospheric air has of holding water in solution, this would be the case every where.

It appears from the experiments of some aëronauts, that the air is much drier in the higher regions than it is near the surface of the earth. Phil. Mag. vol. xix. 373.

* The *formation* of clouds was formerly attributed solely to the solution of water in atmospheric air, and the production of rain to the mixture of airs of different temperatures; but there are so many difficulties attending every hypothesis, that I believe chemists in general now consider these operations of nature inexplicable. The subject is well investigated by Dr. Thomson, in vol. iii. of his System of Chemistry; and he concludes from all the facts, that "the formation of clouds and rain cannot be accounted for by a single principle with which we are acquainted." It is, however, probable that *electricity* alone is the primary cause, and that all the phænomena of nature may originate from this source. See Additional Notes, No 63.

† Saussure conjectures that it is the electrical fluid which surrounds these vesicles, and prevents them from dissolving in the air. These vesicles are said to be from 1.350 to 1.190th of a line in diameter.

An elaborate essay, by Luke Howard, esq. on the various forms which clouds assume, may be seen in the 16th and 17th volumes of the Philosophical Magazine.

See Dr. Darwin's theory of rain and dew, in Notes to the Botanic Garden, 1.e, part i. pages 114 and 169

What further changes take place in this aqueous vapour?

By the operation of causes which are also in a great measure unknown, the clouds after a time become further condensed, and are converted into water.*

What is the consequence of this change of vapour into water?

When the vapour is condensed, it becomes too heavy for the air to support, and falls down in rain,† hail, or snow.

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* It has before been remarked, that a portion of the water which rises in vapour is held in *solution* by the atmospheric air. When two opposite currents of air meet, of different temperatures, the vapours are sometimes condensed thereby, and rain follows. All the known gases have also the property of taking up water and holding it in solution.

It may be remarked, that if the temperature of our atmosphere had been 212°, or upwards, rain could never have fallen upon the earth; for the water taken up by evaporation would have been converted into a *permanently* elastic fluid. It is impossible ever to contemplate the various ways in which the different operations of nature are made to correct and balance each other, without being struck with the infinite comprehension of the Divine mind, which could thus foresee the tendency of every law which it was about to establish. How many cases are there in which the slighest oversight would have produced the destruction of a world!

† It may be observed that rain not only affords a proper degree of moisture to the vegetable creation, but is of service in bringing the soils into a proper state to perform their office. *Dry* earth of itself has little effect; but when *moistened* it has the property of decomposing atmospheric air, and of conveying its oxygen to the roots of those plants which vegetate within it. We are indebted to Humboldt for the knowledge of this fact.

"The clouds consign their treasures to the fields,
And, softly shaking on the dimpled pool
Prelusive drops, let all the moisture flow
In large effusion o'er the freshen'd world."

What is the use of this constitution of nature?

This principle of evaporation is of very general utility:* it is subservient to many natural processes, and is perpetually of use to man in every occupation of life.†

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* This principle of evaporation not only is the primary cause of all rain, mist, dew, &c. but it moderates the effects of the sun's heat by carrying off an immense quantity of caloric in combination with the aqueous vapours. Were it not for the cold produced by evaporation, we should faint under any great bodily exertion, or die by excessive heat. But Nature, always provident, has furnished man with a fluid, which, insensibly perspiring and becoming evaporated from the surface of the body, is the vehicle which carries off the superabundant heat as fast as it is generated. Cold-blooded animals, whose temperature is regulated by the medium in which they live, never perspire; but man, who was intended to live in a variety of climates, and designed for active exertion, is thus preserved from the effects of heat, which would otherwise be destructive. The blood of an inhabitant of the torrid zone is no warmer than that of an inhabitant of the mountains of Lapland; which *may be proved* by placing a thermometer upon the tongue or under the arm. The various means which have thus been adopted for the promotion of our convenience and comfort, are full of instruction and highly gratifying to every reflecting mind.

The operation of this principle may be made apparent by the following experiment: Take a small tube with a little water in it, fold a little lint close round it, and having immersed it in ether till the lint is soaked through, hold it in the air for the ether to evaporate. The cold produced by this evaporation will cause the water in the tube to freeze. If the outside of the glass tube be scratched with a flint or a diamond previous to its being wet by the ether, the effect will more readily take place.

† A little consideration would convince any one of the importance of the principle of evaporation. Innumerable instances of its use might be adduced: suffice it to say, that without it neither grass nor corn could be sufficiently dried to lay up for use. Our clothes when washed could not be dried; neither could a variety of the most common operations be carried on, which conduce much to our comfort and convenience.

CHAPTER II.

OF ATMOSPHERIC AIR.

HAT are the obvious properties of atmospheric*

uidity,† elasticity,‡ expansibility, and gravity.
hat do you mean by the elasticity of the air?
atmospheric air be compressed§ into a small

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he habitable and cultivated parts of the earth are lavishly
ed with every thing to gratify the eye; the diversified ap-
nce communicates pleasure, and prevents satiety; while
hole is surrounded by an atmosphere which preserves
able and animal life. It may be remarked, that to the
parency of this atmosphere we owe all the pleasure we
e from the variegated prospects which the earth affords.
he fluidity of the air was considered in the last chapter.
ages 29, 33.

compass, it has the property of recovering its former state, as soon as the pressure is removed; which is called its elasticity.*

What is meant by the expansibility of the air?

The expansibility of the air is its property of being rarefied by heat, so as to occupy a larger space than it otherwise would.†

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* It is now generally supposed that the air owes its elasticity to the *caloric* which it contains; and that, if it could be deprived entirely of its caloric, it would lose its elastic form.

The rebounding of a common foot ball would be a familiar instance to explain the elasticity of the air to a child.

Bubbles of air rising from the bottom of a glass of water will be seen to dilate as they rise to the surface; owing to the pressure of the liquor becoming less and less.

The air gun and the forcing pump are constructed on this principle. It is by this property of air that fishes are enabled to rise and sink in the water; nature having furnished them with an *air-bladder*, which they have the power of contracting or dilating at pleasure. When the animal compresses this bladder, its whole volume becomes less, and it sinks in the water: when the pressure is removed, the air within the bladder instantly expands, and the creature is enabled to rise.

Mr. Gregory has remarked that, if the air were not elastic, and so fluid as to be easily put in motion, there would be an end to all the melody and harmony which now so much delight us. How admirably is every thing contrived, that it may not only administer to our wants, but be subservient to our pleasures also! That music was designed by the Deity to produce particular effects on man, might be shown very satisfactorily; for who can doubt but

> "That Heaven is pleas'd, when this bright power
> Dispels the clouds of earth, too apt to lower
> On every human mind, in life's precarious hour?"
>
> HAYLEY.

† If the neck of a bladder, containing a small quantity of air, be closely tied up and held to the fire, the swelling of the bladder, by the rarefaction of the air within it, will afford an idea of the *expansibility* of the air.

Mr. Robins has calculated that the air which is disengaged in the firing of gunpowder is rarefied by the heat, so as to

far does the atmosphere extend?

atmosphere is several miles high, but how xtends is not exactly known.*

is the use of the atmosphere?

atmosphere, which is the air we breathe, ssary for the support both of animal and ble life.†

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thousand times the space of the whole of the gun- mployed.

latation or expansion which bodies experience by a vation of temperature, is much more considerable in ids than in liquids. Atmospheric air is an instance of of this chemical axiom. Whenever this expansion e, caloric is absorbed.

atmosphere were of the same density throughout, might be known by its effect in raising a column of mercury; but as it increases in rarity the higher it

Is the atmosphere of use in any other respect?

The atmospheric air is necessary in every instance of combustion:* it ministers to several of the pleasures which we derive from our senses;† it gives buoyancy to the clouds, and enables the

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ment for the various tribes of creatures which inhabit it: and when covered with a crust of ice, cavities are formed in the ice as it freezes, by which means a communication between the external air and the subjacent water is preserved; in order to support the life of those beings which reside there.

"The vital air
Pervades the swarming *seas* and heaving earths,
Where teeming Nature broods her myriad births;
Fills the fine lungs of all that *breathe* or *bud*,
Warms the new heart, and dies the gushing blood;
With life's first spark inspires the organic frame,
And, as it wastes, *renews* the subtil flame." DARWIN.

It is to the presence of air that water is indebted for its agreeable taste. Boiling deprives it of the greater part of it; hence the insipidity of boiled water.

* There is one *exception* to this axiom. If a combustible substance be mixed with one *fourth* or one half its weight of nitre, or with oxygenized muriate of potass, it will burn if atmospheric air be excluded. But this is owing to oxygen, one of the principles of the atmosphere, being afforded by these salts. See chap. xii. on Combustion.

† Were it not for atmospheric air, we should be unable to converse with each other; we should know nothing of sound, or of smell, or of the pleasures which arise from the variegated prospects which now surround us. It has been well remarked, that, if the Deity had intended only to give us existence, and had been indifferent about our happiness or misery, all the necessary purposes of hearing might have been answered without harmony; of smell, without fragrance; of vision, without beauty.

Perhaps nothing tends to give so satisfactory an assurance of the goodness of the ALMIGHTY, as the consideration of the various *uses* to which the different substances in Nature may be applied. With this view I copy what an elegant French writer has said on this necessary fluid. "In the use of atmospheric air, *man* is the only being who gives to it all the modulations of which it is susceptible. With his voice alone, he imitates the hissing, the cries, and the melody of all animals:

t other advantages do we derive from this
on of the atmosphere?

e had little or no atmosphere, we should
o cold water; for the waters on the face of
rth would all evaporate at a very inferior
rature:* besides, the arterial vessels of all
zed beings would be so constantly distend-
at animal and vegetable life would be en-
ed.

---

explain how the successive columns of water force up
e in the pump tree, and how that valve supports the
hen raised, and prevents its return.

ress'd by the incumbent air, the floods below,
hrough opening valves, in foaming torrents flow,
oot after foot in lessen'd impulse move,
nd rising seek the vacancy above." DARWIN.

mmon syringe (which may be bought for a few pence)

How are waters and other fluids preserved to us by the weight of the atmosphere?

The weight of the atmosphere, pressing on the water, binds it down as it were, and prevents the usual heat of the sun from converting this and all other fluids on the face of the earth into vapour.*

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ment, and shows that a very small degree of heat would be sufficient to evaporate most of our fluids if we had no atmosphere. This instrument is also calculated to show that evaporation produces cold; for the instant that the spirit begins to boil, a sensation of sudden cold is felt on that part of the hand where the bulb rests.

It is the principle of *evaporation producing cold* that occasions the injury which persons sustain by sitting in wet clothes. In these circumstances, it is not the water that hangs *upon* them which produces the mischief, but the sudden loss of a large portion of caloric, which is carried off from the body by the evaporation of this water. If a healthy person were closely covered up with his wet clothes, so that no evaporation could take place, he would probably sustain no injury.

* That the waters on the face of the earth would be dissipated in vapour by a *small* degree of heat, if we had no atmosphere, may be shown by the following simple experiment:—Procure a bottle with a very long neck, fill it with boiling water, and cork it close, so as to exclude the air. Then if it be put to stand in a basin of cold water, the water will sink in the neck of the bottle as it cools. The shrinking of the hot water will produce a vacuum in the upper part of the bottle, and the water within it will be seen to recommence its boiling with great violence. This can be owing to nothing but the cork taking off the pressure of the atmosphere from the water. In like manner, water which has been cooled many degrees below boiling, will begin to boil again if placed under the receiver of an air pump, as soon as we begin to exhaust the receiver of its air. Under the pressure of the atmosphere water boils at 212°, but in vacuo it boils when heated only to 67°. On the contrary, if additional pressure be given to water by a Papin's digester, it may be heated to 300°, without ebullition. Lead has often been melted by the water heated in these digesters.

At the boiling fountain in Iceland, the water is thrown to the height of 90 feet, and is still boiling hot when it falls to the ground. This water, therefore, must have been much hotter.

How does the weight of the atmosphere operate so as to be beneficial to the animal and vegetable creation?

The uniform pressure of the atmosphere on the *exterior* of all organized beings counterpoises the *internal* pressure of the circulating fluids, and preserves the vessels in due tone and vigour.*

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in its reservoir, than the boiling point of water. See Troil's Account of Iceland.

Some philosophers have asserted that, if atmospheric pressure were entirely removed, all substances on the face of the earth, solid as well as fluid, would be dissipated in vapour.

If a small metallic cup be half filled with good ether, and placed within a large watch glass half filled with water, and both be put under the receiver of an air pump, when the air is exhausted the ether will boil, and the water will be frozen. The cause of these effects may be thus explained:—When the pressure of the atmosphere is removed by the air pump from the surface of the ether, its own latent caloric occasions its expansion, and, absorbing caloric from the water, it becomes converted into gas; and the water, having lost its caloric of fluidity, becomes ice.

The best elucidation of the nature of the pressure of the atmosphere which I have seen, is in "Brisson's Physical Principles of Chemistry," section 31 and the following.

* Were it not for the pressure of the atmosphere constringing the vessels in men and vegetables, the elastic fluids contained in the finer vessels would inevitably burst them, and life become extinct. Count Zambeccari and his companions, who ascended with a balloon to a great height on the 7th of November, 1783, found their hands and feet so swelled, that it was necessary for surgeons to make incisions in the skin. They ascended to so great a height, that the pressure of the atmosphere was not sufficient to counterbalance the pressure of the fluids of the body.

Persons who have delicate constitutions need not wonder that they are generally much affected by a change in the atmosphere, when they learn that often in the course of a few hours the atmospheric pressure, on each individual, is increased or diminished from one hundred weight to half a ton weight: while the *internal* pressure of the circulating fluids remains the same. Supposing a man's body to contain 15 square feet of surface, (which is near the truth,) he will sustain a body of air upwards of fourteen tons weight. But it is necessary to remark that the air presses upwards, downwards, and sideways, in every

What is the weight of the atmosphere?

Each square foot of the earth's surface sustains about 2160 pounds of atmospheric air. A column of air an inch square weighs about 15 pounds.*

What other advantages do we derive from this immense atmosphere?

The great thickness of the atmosphere gives a proper temperature to the rays of the sun: it also reflects those rays so as to give a lucid brightness to every part of the heavens;† and is the cause

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direction; and that it is owing to this equal pressure that we are not injured by the vast weight of the atmosphere; for the equal pressure on all sides resists as much as it is resisted.

Whenever I hold my hand out in this fluid, I feel no weight upon it, because the pressure under and above my hand is equal: but if I lay my hand on a hollow cylinder of glass, placed on the plate of an air pump, and exhaust the air out of the cylinder, I become immediately conscious of something that presses it so *forcibly* to the glass, that I cannot release it. The prop is now gone; I have no pressure under my hand; a column of air 45 miles high forces it down by its weight, and I must let in the air under it, before the hand can be withdrawn.

Mr. Coates computed that the weight of the air which presses upon the whole surface of the earth, is equal to that of a globe of lead sixty miles in diameter.

* A column of air of the height of the atmosphere, when greatest, is equal to a column of water 35 feet high, or a column of mercury of the same size 30½ inches high. Hence water will not rise in a pump more than 35 feet, nor mercury in a barometer stand higher than 30½ inches. See Additional Notes, No. 12.

A quart measure of atmospheric air weighs about seventeen grains.

† If there were no atmosphere surrounding the earth, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back to the sun, he would directly perceive it as dark as night; for in that case there would be no substance to reflect the rays of the sun to his

e dews and rains which make the earth

*

you learnt any thing of the nature† of the
h forms the atmosphere of this earth?

immense atmosphere is composed of a
chiefly of two different airs,‡ which are
ed§ in certain proportions.‖

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is owing to refraction that the sun enlightens the earth
e before it rises, and some time after it sets. See this
with perspicuity by Gregory, in his Astronomical
page 78—82.

atmosphere is the cause of evaporation; it is the at-
c air which holds the aqueous vapours in solution, and
them in a gaseous state till they are condensed again

he discovery of the composition of atmospheric air, we
ed to Scheele, whose genius, when very young, ena-
to break the trammels of a dependent situation, and

*What do you call these airs which compose our atmosphere?**

They are called oxygen air† and nitrogen air.

Are oxygen and nitrogen the only substances which enter into the composition of the atmosphere?

No; atmospheric air contains also one part in every thousand‡ of carbonic acid gas,§ and several adventitious substances.

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to a careful analysis of the contents of a glass balloon that had been filled with air at the height of 20,000 feet from the earth, it was found similar in every respect to that taken from the surface. Nicholson's Journal, vol. x. 286.

* Atmospheric air is a mixture of two distinct and *solid* substances, viz. oxygen and nitrogen rendered aërial by the expansive power of caloric: it likewise contains a portion of carbonic acid gas.

Oxygen and nitrogen, combined in various proportions, form also no less than three other compounds, viz.

Nitric acid consisting of about 4 parts oxygen to 1 of nitrogen.				
Nitrous gas, of	3	do.	to 1	do.
Nitrous oxide, of	1	do.	to 2	do.

† The respirable part of *atmospheric* air *has* been called oxygen, on account of its acidifying principle: the other part has been termed azote, from its known quality of killing all animals that are obliged to breathe it, when separated from oxygen. The terms are taken from the Greek language. I have in this work adopted *nitrogen* in preference to azote, because it is the base of nitric acid, and it agrees in termination with oxygen and hydrogen. Carbonic acid gas and hydrogen gas are as incapable of supporting life as nitrogen; therefore there is no reason why one should be called azote more than the other.

It should be remarked, that oxygen denotes the solid base of atmospheric air, and that this requires *light* as well as caloric in order to convert it into oxygen gas. During combustion, the vital air gives out this light in every direction.

‡ The proportion of carbonic acid gas in atmospheric air was formerly calculated at one per cent.; but Mr. Dalton has lately demonstrated that it does not amount to more than one part in a thousand. Manchester Mem. N. S. vol. i. 254.

§ If a pure alkali be exposed to the atmosphere, it will gradually absorb carbonic acid. This is also the case with se-

at other substances are found in atmospheric

ides carbonic acid gas,* it holds a por-
of water in solution ;† and sometimes
ns hydrogen and carburetted hydrogen
‡

at are the sources of these other gases ?

bonic acid gas is constantly formed by the
ation of animals and by combustion ;§ and

---

the metallic oxides. As atmospheric air is always fur-
with carbonic acid, no wonder that so large a number of
s are found in the state of carbonates.

onic acid gas is found to exist in the atmosphere not
ar the surface of the earth, but at the greatest heights.
e found it at the top of Mont Blanc, which is esteemed
hest point of the old continent. However, it is pro-
at the proportion of carbonic acid is not so large at great

hydrogen and carburetted hydrogen gases arise from various sources, particularly from marshes, stagnant pools, &c. all which are prejudicial to the animal creation.

If carbonic acid air and carburetted hydrogen air are prejudicial to animal life, how are they corrected in the atmosphere?

These airs which would cause the death of any animal obliged to breathe them,* are the proper nutriment of vegetables, and nature has endowed them with organs for their decomposition.

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had not the Almighty provided means for its being as rapidly decomposed. The wisdom and goodness of this appointment must be apparent to those who know that whenever atmospheric air becomes charged with one tenth of this gas, it is unfit for promoting combustion, and is fatal to most animals that are obliged to breathe it.

* Every chemist must be aware that a large quantity of *carburetted hydrogen gas* is perpetually evolved at the surface of the earth; he must also know that this gas is fatal to animal life. I could adduce a melancholy instance of a gentleman who inhaled it by mistake, and died almost immediately in consequence of it. How then has the all-wise Artificer of the world contrived to protect its inhabitants from the baneful influence of that immense quantity with which the atmosphere is perpetually contaminated? The means are as simple as they are important.—Vegetables are so constituted that carbon and hydrogen are the necessary food of plants, and conduce to the support of vegetable life: their vegetating organs seize the carbonic acid gas which comes within their reach, and while they appropriate the *carbon* to themselves, the *oxygen* is thrown off to renovate the atmosphere by its union with the nitrogen rejected by animal respiration. As all vegetables are in want both of carbon and hydrogen, there can be little doubt but that by their means the atmosphere is divested of carburetted hydrogen gas also. Thus, what is noxious to man is rendered beneficial to vegetables; and the oxygen which vegetables are not in want of, is separated by them in its utmost purity for the use of

Is there much difference in the nature of these gases?

Yes: they are of different and opposite qualities.*

What are the properties of oxygen gas?

The oxygen gas in atmospheric air is the principle of combustion,† and the vehicle of heat;‡

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atmospheric air, fire would lose its strength, candles would not diffuse such complete light, and animals would with difficulty separate the necessary quantity of the vivifying oxygen. On the other hand, if the atmosphere were more charged with oxygen than nitrogen, animals indeed would acquire a freer respiration; but let us consider the activity which fire would acquire by air of superior purity. We know that, on some occasions, the least spark excites the strongest flame in a combustible body, and which increases so much as to consume it in a few moments: candles *then* would be no sooner lighted than they would be destroyed, without answering any other purpose than that of dazzling us for a few moments: iron would be calcined, instead of acquiring from the fire that softness necessary for transforming it into various instruments, and which it cannot receive in a more moderate heat. Nothing would be capable of checking the progress of this destructive element, which is nourished by vital air, if this aëriform substance were not abundantly mixed with mephitic air, which serves to restrain it." *Anthony de Marti* on the Constitution of the Atmosphere.

* These gases are of such opposite qualities, that the one is sometimes called *vital* air; while the other, from its causing the death of those who breathe it, is by the French chemists (as has before been remarked) called azotic gas.

† The necessity of oxygen for supporting combustion may be shown by the following simple experiment. Pour a little water on a flat dish, place two or three lighted wax tapers of different lengths in the water, and invert a tall glass jar over them. The flame of the different tapers will soon be seen to grow smaller, and at length will be extinguished in succession. That which is highest will be extinguished first, and the shortest taper the last, owing to the purer air occupying the lower part of the jar.

‡ Dr. Higgins having caused a young man to breathe pure oxygen gas for several minutes, his pulse, which was at 64, soon rose to 120 beats in a minute. By abstracting a part of the oxygen from atmospheric air, the pulse may likewise be lowered at pleasure. Pure oxygen gas has been used also with

and is absolutely necessary for the support of animal life.*

What is the nature of oxygen gas, when in a separate state?

Pure oxygen gas has the property of accelerating the circulation of all the animal fluids, and occasions the most rapid combustion of all combustible substances; so that it is the most energetic and powerful agent that we are acquainted with.

What is the specific gravity of oxygen gas?

Oxygen gas is a little heavier than atmospheric air,† and 7·10 times lighter than water.

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success in case of suspended animation. See Additional Notes, No. 6 and 8.

Water impregnated with oxygen gas has been found a valuable remedy in some particular diseases. By depriving common water of atmospheric air by boiling, and then forcing oxygen gas into it, I have occasioned a large absorption of it, and have found that it retained it better than carbonic acid gas is retained by water. Later experiments by Dr. Henry have determined that water takes up $\frac{1}{27}$ of its volume at 60° whatever be the density of the gas.

* It has been proved by Mr. Hassenfratz, that oxygen is necessary to promote the vigour of plants as well as that of animals; and that, to this end, a much larger quantity of oxygen is combined with snow, and in rain water, than in river or spring water.

"LEAVES, LUNGS, and GILLS, the vital ether breathe
On earth's green surface, or the waves beneath."

A collection of experiments on the effects of oxygen on animal and vegetable life may be seen in "Archer's Observations on Oxygen," 8vo, 1798. See Additional Notes, No. 6.

† At the temperature of 54.50, when the barometer stands at 28 inches, oxygen gas is 12 drachms (or 1½ ounce) to each cubical foot: whereas nitrogen gas is only 10 drachms 48 grains to the cubical foot.

Oxygen gas is plentifully procured from nitre, or from the black oxide of manganese. Four ounces of nitre melted with a little slacked lime, produced Mr. Ingenhousz 3000 cubic inches of vital air. See Additional Notes, No. 7.

are the principal properties of nitrogen gas?

gen gas or azote is chiefly distinguished ain *negative* qualities, such as its being in- of supporting combustion and animal life. inflammable and somewhat lighter than heric air.*

g that nitrogen gas is injurious to animal at is the use of so large a quantity of it in eric air?

gen gas has the effect of neutralizing, in easure, the properties of oxygen gas, and ng it fit for respiration and combustion.†

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some late experiments its seems probable that nitro- a simple substance. See Phil. Magazine, vol. xxxiii. Indeed, the experiment of Dr. Priestley, by which ed several portions of nitrogen from the same distilled

How is this change effected by nitrogen gas?

By the union of nitrogen gas with oxygen gas: the latter, which would burn every thing within its reach with an unparalleled activity, is, as it were, dissolved and diluted; and the nature of the former is so much enveloped by the latter, that the compound possesses properties different from either of these gases, so as to be fitted for every purpose for which it was designed.*

How does atmospheric air support life.†

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stimulant, the circulation would become accelerated, and all the secretions would be increased; but the tone of the vessels, thus stimulated to increased action, would be destroyed by over-excitement; and, if the supply from the stomach were not equal to the consumption, the body must inevitably waste and decay." —(Dr. Lambe.)

* Though nitrogen gas is, by itself, so noxious to animals, it answers an important end when mixed with oxygen gas in atmospheric air. Were it not for this large quantity of nitrogen in the atmosphere, the blood would flow with too great rapidity through the vessels, and all animals would have too great spirits; the consequence of which would be, that the life of man would not be protracted to the length that it now is.

" From Nature's chain whatever link you strike,
Tenth, or ten-thousandth, breaks the chain alike."

Nitrogen gas has been medicinally administered with success in cases of increased irritability, such as inflammation, &c. See Fourcroy's General System of Chemical Knowledge.

† The necessity of atmospheric air, for the support of life, was exemplified by a melancholy accident which happened to two men in the bay of Dublin, who went to visit a wreck in a diving-bell. Two barrels of fresh air were to be alternately sent down to them, and the contaminated air was to be let out by a stopcock at the top of the bell. But by the contraction which ropes suffer in being wet, the bell turned round in its descent, and entangled the strings by which the divers meant to ring bells, and indicate their wants to the people on board the ship from whence they were lowered. Waiting too long for these signals, the bell was raised, and the divers were both found dead. They were not drowned, but died, like the unhappy people in the hole at Calcutta, for want of a supply of pure air.

By giving out its oxygen and caloric to the blood.*

What do you mean by caloric?

Caloric is the name which modern chemists have given to fire, or the matter of heat; a large portion of which is intimately combined with atmospheric air.†

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* Dr. Priestley has shown, by a variety of experiments, that the blood perpetually receives oxygen gas (or what he calls dephlogisticated air) from the atmosphere, by the agency of the lungs. See his Experiments on Air.

"The blood is *purple* when it arrives at the lungs; but having there thrown off hydrogen and charcoal, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries; the source of animal heat; and the cause of sensibility, irritability, and motion."—Thornton's Philosophy of Medicine.

Black venous blood, exposed to the air, becomes red on its surface; and air, remaining confined over venous blood, loses its oxygen, so that what remains is found to be unfit for combustion. These facts prove that the vermilion colour of the blood is owing to the inhalation of oxygen gas.

"The internal surface of the lungs, or air vessels, in man, is said to be equal to the external surface of the whole body: it is on this *extended* surface that the blood is exposed, through the medium of a thin pellicle, to the influence of the respired air." See Additional Notes, No. 3.

"'Tis surely God
Whose unremitting energy pervades,
Adjusts, sustains, and *agitates* the whole.
He ceaseless works alone; and yet alone
Seems not to work: with such perfection fram'd
Is this complex stupendous scheme of things." Thomson.

By the rise of the breast-bone in man, and the descent of the diaphragm, room is afforded for 42 cubic inches of atmospheric air at every drawing in of the breath. A deeper inspiration will give room for more than twice this quantity. Keill's Anatomy.

† This name was given by the framers of the new nomenclature to the matter of heat, which they always distinguish from the effect. Caloric is applied to fire, or the substance which produces the sensation we call heat, but never to the sensation itself, or the effect produced by fire. In this case it is said that caloric raises the temperature of bodies, or, on the contrary, that the temperature is lowered by the loss of caloric.

Is the caloric which is combined with the air we breathe sufficient of itself to keep up the necessary heat of the body?

Animal heat is preserved chiefly by the inspiration of atmospheric air. The lungs, which imbibe the oxygen gas from the air, impart it to the blood; and the blood, in its circulation, gives out the caloric to every part of the body.*

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* Dr. Menzies ascertained that the blood in its passage through the lungs gains more than one degree of Fahrenheit's thermometer. Dr. Menzies on Respiration.

Dr. Crawford instituted a series of experiments, with a view to discover the cause of animal heat. In the course of his inquiry, he found that blood contains a much greater quantity of *absolute* heat than the elementary substances of which it is composed, and that in its change from venous to arterial blood it acquires a greater *capacity* for caloric; by which admirable contrivance, any rise of temperature in the lungs which would be incompatible with life, is prevented. Nothing can afford a more striking proof of creative wisdom, than this provision for the preservation of an equable animal temperature. By the decomposition of atmospheric air, caloric is evolved, and this caloric is taken up by the arterial blood, without its temperature being at all raised by the addition. When it passes to the veins, its capacity for caloric is diminished, as much as it had before been increased, in the lungs: the caloric therefore, which had been absorbed, is again given out; and this slow and constant evolution of caloric in the extreme vessels over the whole body, is the source of that uniform temperature which we have so much occasion to admire.

This same chemist has ascertained that whenever an animal is placed in a medium the temperature of which is considerably high, the usual change of arterial into venous blood does not go on; consequently, no evolution of caloric will take place, and the animal heat will not rise much above the natural standard. How pleasing is it to contemplate the arrangements which the Deity has made for the preservation and felicity of his creatures, and to observe that he has provided for every possible exigency!

According to Lavoisier, a man generally consumes 32 ounces troy of oxygen gas in 24 hours; that is, the lungs separate this quantity of oxygen gas from the air which he respires in that time.

The blood, in passing through the lungs to take up oxygen

How do clothes conduce to preserve the heat of the body?

As the temperature of the atmosphere in this climate is always inferior to the animal temperature,*

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gas, throws off charcoal; for there is a larger portion of carbonic acid gas thrown out in every respiration than could be furnished by the atmosphere.

Lavoisier has shown that, in respiration, there is a constant combination of the oxygen of the atmosphere with the hydrogen and carbon of the blood. See Additional Notes, No. 9.

" Thus LIFE discordant elements arrests,
Rejects the *noxious*, and the *pure* digests;
Combines with heat the fluctuating mass,
And gives awhile solidity to gas." DARWIN.

See a good Memoir on Respiration, and the Production of Animal Heat, by Armand Seguin, in the 6th volume of the Monthly Magazine, page 94: but this subject is treated more at large by Dr. Bostock, of Liverpool, than any other writer: to his work I would refer the reader.

* Those animals which do not breathe, such as fishes and insects, have a bodily temperature but little superior to the medium in which they live. The temperature of all animals is proportioned to the quantity of air which they breathe in a given time. Man, quadrupeds, and the whale tribe, have a heart, and breathe through lungs; in consequence of which structure heat is evolved during the circulation of the blood. They are therefore called warm-blooded animals. In the severest winter, or in the coldest regions that man or any quadruped can inhabit, the temperature of the body is hardly a degree lower than in the warmest summer, or in the torrid zone. A thermometer with its bulb under the tongue, or buried in a wound in any fleshy part of the body, always indicates a heat of 97° or 98°, be the temperature of the air what it may.—(Skrimshire's Essays.) This astonishing effect is produced by the decomposition of atmospheric air, as explained in the preceding notes. A postulatum has been assumed by some atheists, that the organs of the body have been formed by what they call *appetency*, i. e. endeavour perpetuated, and imperceptibly working its effects through a long series of generations: but I would ask any man of common understanding, whether he would like to assert that he believes this to have been the way in which the lungs acquired the faculty of decomposing atmospheric air; and that this hypothesis is sufficient to account for *the composition of this air*, which so exactly suits the operation of these lungs, and

clothes* are necessary to prevent the sudden escape of that heat from the surface of the body† which the lungs have separated from the atmosphere.

What becomes of the nitrogen which was combined with oxygen in atmospheric air?

The greatest part of the nitrogen is thrown out of the lungs at every respiration;‡ and being some-

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which contains that exact portion of caloric which the animal economy requires! It is worthy of remark, that cold-blooded animals, which are not furnished with this breathing apparatus, are so constituted that their temperature changes with every change of the temperature of the surrounding medium. Frogs have been absolutely frozen so as to chip like ice, and yet when carefully and gradually thawed have been completely reanimated.

* Clothes keep the body warm in consequence of the air which they infold within them; atmospheric air being a non-conductor of heat. It is on this principle that double windows preserve the warmth of apartments at an equable temperature. In like manner double lids for boilers, formed so as to hold a sheet of air, are found to be very effectual for preserving the heat of the liquor with a very small portion of fuel.

On this principle it is, *that light spongy substances*, such as furs and down, afford the warmest clothing. Hence it is that the carpet which covers the earth in winter, is spread out by Nature with so light a hand, that it might hold an abundance of atmospheric air within its interstices, to preserve the warmth of those innumerable tribes of vegetables which it is destined to protect.

† We clothe ourselves with wool, because it is a bad conductor of heat and retards its escape from the body. The inhabitants of Russia clothe themselves in fur, because fur is still a worse conductor of heat than wool. Sheep are natives of a temperate climate; but the bear and the ermine of the coldest. The provident care of the Creator is evidently conspicuous in this appointment, and discovers the same undeviating attention to the comfort of all his creatures: hence the clothing of animals in the torrid zone is hair, in the temperate zones wool, in the frigid thick fur.

‡ It is not simple nitrogen which is thrown out, but *nitrogen gas*; and it has been imagined, that when atmospheric air is decomposed by the lungs, part of the disengaged caloric is required for the nitrogen, to preserve it in the form of gas: but

what lighter than atmospheric air, it rises into the atmosphere to await fresh combinations.*

What provision has nature made for restoring the vast quantity of oxygen which respiration and combustion are perpetually taking from the atmosphere?

The leaves† of trees and other vegetables give

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it is a curious fact, that nitrogen gas and carbonic acid gas, both which are thrown off in the act of respiration, have less capacity for caloric than any other gaseous substance. It is a general characteristic of the gases, that they absorb a large portion of caloric to preserve them in a gaseous form. Yet one of these gases has less capacity for caloric than many liquids, and the other (nitrogen gas) less capacity than even ice. Could any thing possibly have been better contrived for the preservation of that portion of caloric, which is necessary to keep up the animal temperature!

It may be remarked, that the interval which there is between every inspiration seems to have been designed, to allow time for the nitrogen gas which is thrown out of the lungs to mount in the air above the head, in order that a fresh portion of air might be taken in, and that the same air might not be repeatedly breathed. That this actually entered into the plan of the Divine mind, may be presumed from the levity which has been given to nitrogen gas, and which enables it to rise in atmospheric air. See Additional Notes, No. 53.

* It may be observed that, if the specific gravity of the two constituent parts of atmospheric air had been reversed, the nitrogen thrown off by the respiration of men and animals would have perpetually occupied the lower regions of the atmosphere, and produced universal pestilence. Nitrogen gas is very little lighter than atmospheric air, but probably to that *little* the atmosphere owes the salubrity it possesses. How provident has the Almighty been, in thus foreseeing the operation of those laws which were designed to promote the welfare of every species of animated beings!

"A vessel of 1000 cubic inches will contain 315 troy grains of common air; but it will contain 335 of oxygen gas, and only 297 of nitrogen gas." Dr. Black's Lectures, vol. ii. 109.

† The *upper* side of the leaf is the organ of respiration; hence some vegetables (as they give out oxygen only in the day) close the upper surfaces of their leaves during the night. The multiplicity of the leaves of trees, &c. indicates the importance of transpiration to a vegetable.

out during the day a large portion of oxygen gas,* which, uniting with the nitrogen gas thrown off by animal respiration, keeps up the equilibrium, and preserves the salubrity of the atmosphere.

Is this perpetual renovation of the atmosphere owing to a fortunate concurrence of circumstances, or is it the effect of design and contrivance?

When we recollect the various processes of nature and art, which concur with respiration and combustion in depriving the atmosphere of

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* To show the production of oxygen gas from the leaves of plants, fill a glass bell with water, introduce leaves under it, and place the bell inverted in a flat dish of water. Expose the apparatus to the rays of the sun, and very pure oxygen gas will be disengaged, which will displace the water in the jar, and occupy its place. In like manner a sprig of mint, corked up with a small portion of carbonic acid air and placed in the light, renders it again capable of supporting life. The plant purifies what the animal had poisoned.

Thus, while the vegetable tribes inhale
The limpid water from the parent vale,
Their vegetating organs decompose
The salutary compound as it flows,
And, by affinities unknown, dispart
The subtile hydrogen, with chemic art,
To blend it with the carbon of the soil,
And form bitumen, resin, wax, or oil.*
The freed caloric bursts the expanding mass,
And swells the nascent oxygen to gas;
Which, from its inmost cells, each leaflet pours
In vital currents through its myriad pores,
To renovate the air, by tempests hurl'd
From pole to pole, around a freshen'd world.

All the oxygen is not given out by plants; part must be retained to form the sugar and acids which are found in vegetables. Mr. Cruickshank has shown by experiment, that oxygen is absolutely necessary for the conversion of mucilage into sugar.

* For more on this subject, see the account of the decomposition of water, chap. iv. of this volume.

its oxygen; and that, notwithstanding the atmosphere uniformly contains every where the same proportion of this gaseous substance,* we can attribute the renovation to nothing but design, and perceive in it a proof that the laws of nature must be referred, not to blind chance, but to unerring intelligence combined with infinite goodness.†

(Rollo on Diabetes.) Plants also absorb nitrogen from the atmosphere with avidity; and this is another means of keeping up the standard purity of atmospheric air.

* It has been found that the air of the most crowded cities contains as much oxygen gas as that of other places. This was demonstrated by Priestley soon after he became engaged in making experiments with his eudiometer.

† All kinds of vegetables, when assisted by the rays of the sun, have the power of decomposing water; during which decomposition the hydrogen is absorbed, and goes to the formation of oil and resin in the vegetable; while the oxygen combines with part of the caloric received from the sun, and is given out in the form of oxygen gas; so that this *one operation* of nature gives nourishment and provides materials of growth to the vegetable world, and, at the same time, renovates that vital principle in the atmosphere which is necessary for the support of the animal creation. Surely nothing short of consummate wisdom could have conceived any thing half so beautiful in design, or extensively and superlatively useful in effect. See Additional Notes, No. 10 and 18.

CHAPTER III.

OF CALORIC.

WHAT is heat?

Heat is the well-known sensation which we perceive on touching any substance whose temperature is superior to that of the human body.*

What name is given to the matter of heat?

Chemists have agreed to call the matter of heat *caloric*,† in order to distinguish it from the sensation which this matter produces.‡

What are the uses of caloric?§

Caloric is every where indispensable to the

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* The sensation of heat and cold arises from the tendency which caloric has to diffuse itself equally amongst all substances that come in contact with it. If the hand be put upon a hot body, part of the caloric leaves the hot body and enters the hand: this produces the sensation of *heat*. On the contrary, if the hand be put upon a cold body, part of the caloric contained in the hand leaves the hand to unite with the cold body: this produces the sensation of *cold*.

Some of the methods of producing artificial cold, may be seen in Mr. Walker's papers in the Philosophical Transactions for 1795 and for 1801, and in Watson's Chemical Essays.

† In answer to the question, What is the *cause* of caloric? it may be necessary to state, that philosophers have differed in their opinions on this subject. Some have considered it merely the consequence of a peculiar motion among the particles of bodies, and that it has no existence independent of motion, any more than sound has. Others have supposed that it is really a distinct substance, which exists independent of every other. The latter is the general opinion at present.

‡ In order to give precision to chemical language, it was necessary to find a term to distinguish the matter of heat from its effect; for, whenever caloric becomes fixed in a body, it loses its property of affording heat. Nothing can be more evident than that caloric may exist in many substances, without producing any of the effects which arise from the agency of fire.

§ Many of the uses of fire will immediately occur to every

existence of man. "It is with fire that, in every country, he prepares his food, that he dissolves metals, vitrifies rocks, hardens clay, softens iron, and gives to all the productions of the earth the forms and combinations which his necessities require."

What are the sources of caloric?

There are six sources from whence we procure caloric; viz. from the sun's rays, by combustion, by percussion, by friction, by the mixture of different substances,* and by means of electricity and galvanism.

Which of these is the principal source of caloric?

The sun is the principal, and, probably, the original fountain which furnishes the earth with a regular supply,† and renders it capable of

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individual, whenever the importance of this subtile fluid is alluded to; though perhaps the wisdom of the Deity, in giving the use of it to man only, has not been often noticed. Why has this powerful agent been solely intrusted to man? Why was every fowl of heaven, and every beast of the field, impressed with an unconquerable dread of approaching it? If it were at the disposal of animals, which of our possessions, or even of our lives, would be safe for a single moment!

* These are the chief sources of caloric with which we are acquainted; but there are instances of *spontaneous* combustion on record, which are unaccountable. The most remarkable case that I have seen, is related in the Philosophical Magazine, vol. xvi. 92. See also an interesting memoir on this subject, vol. xviii 346.

Perhaps *compression* might with propriety be added to this list. See an account of M. Biot's Experiment, in a note, page 132; and also of the effects of the sudden compression of atmospheric air, in the chapter on *combustion*, page 461.

† Caloric comes to us from the sun at the rate of 200,000 miles in a second of time;* but Dr. Herschel has proved, that

* See Additional Notes, No. 59.

supporting the animal and vegetable creations.*

How is caloric furnished by combustion?

The oxygen gas of the atmosphere is *decomposed* by combustion; and caloric, one of its component parts, is set at liberty.†

How is caloric produced by percussion?

The heat produced by percussion is generally occasioned by the *compression* of the particles of the body, which compression forces out a portion of its latent caloric.‡

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the solar rays which occasion heat, are distinct from those which illuminate and produce vision. Such investigations have a tendency to impress us with the most sublime ideas of the economy of the universe, and to convince us of the infinite resources of its Divine Author.

> "Great source of day! for ever pouring wide,
> From world to world, the vital ocean round,
> On Nature write, with every beam, His praise."

* According to the laws of nature, animal and vegetable life are both very much influenced by the temperature in which they exist; we therefore find different kinds of vegetables, and a different race of animals, appropriated to the different climates of the earth.

That caloric is as necessary for the support of vegetable as it is for that of animal life, may be proved by direct experiment. If in the midst of winter a hole be bored in a tree, and a thermometer put into it, it will be seen that the tree is many degrees warmer than the atmosphere. Walker, vol. i. 198.

† We are indebted to Lavoisier for the discovery that caloric is disengaged from atmospheric air by combustion: it was he who pointed this out as a general law of nature, "that in all cases of combustion, oxygen combines with the combustible, during the act of combustion." For a further explanation of this phenomenon consult the chapter on *combustion*.

‡ As evaporation produces cold, condensation always occasions heat: that is, caloric is always evolved from those bodies which have undergone any degree of condensation. In one case caloric is absorbed, in the other it is set at liberty.

By the collision of flint and steel so much caloric is disen-

is caloric produced by friction?

not known how friction produces caloric,* we suppose it to be a succession of per- ns; or it is probably to the agency of elec- or galvanism alone we must ascribe the

what way can heat be produced by means of ity or galvanism?

the discharge of an electrical battery, or by lvanic apparatus, a more intense degree of may be obtained than by any other means ver.†

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hat the metallic particles which are struck off are actu- ted thereby. This is evident, from their being always a spherical form. See note †, page 74.

Thomas Wedgwood took a piece of common win-

How is caloric produced by mixture?

When heat is produced by the mixture of two or more substances, it is owing to the fluid part of the mixture taking a more solid form ;* for neither water nor any other fluid can acquire an increase of density without giving out a portion of its latent caloric.†

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be inflamed by galvanism, the light produced seems to vie with that of the sun, being too intense for the eye to endure.

With Mr. Pepys's apparatus, charcoal has been deflagrated by the galvanic power, after passing through 16 persons with wetted hands joined. But the effects produced by the immense battery of the Royal Institution, and which consists of two thousand double plates, making a surface in the whole of 128,000 square inches, far surpass any thing before seen. The plates are arranged in cells of porcelain, and when the cells were filled with diluted nitric and sulphuric acids, quartz, the sapphire, magnesia, lime, &c. all entered into fusion, and platina became fluid as readily as wax would melt in the flame of a taper. *Davy's Chemical Philosophy*, vol. i. p. 152.

* Whenever two gases or liquids unite *chemically*, the compound has greater density than the mean density. Thus the vapour of water, at the heat of ebullition, occupies much less space than the hydrogen gas and oxygen gas, which compose it, would have occupied at the same temperature. Nitrous gas has a specific gravity greater than that of the simple mixture of its two elements: it is the same with ammoniacal gas; and this latter, though its elements are already greatly condensed, experiences a new condensation when it combines with muriatic acid gas; which is even so considerable, that both take a solid form. Berthollet.

† Sulphuric acid and water experience this condensation by mixture, which is proved by the measure of the fluids, before and afterwards, and by the heat that is evolved. If four parts of the former be mixed with one of the latter, the mixed fluids will quickly acquire a temperature higher than that of boiling water. It is necessary to be cautious in making this experiment.

If iron filings and sulphur be mixed into a paste with water, a sulphuret of iron will be formed, which decomposes the water and absorbs oxygen so rapidly that the mixture takes fire, even though it be buried under ground.

Mixture does not uniformly produce heat. The mixture of

speak of latent *caloric; is there any differ-*
the nature of caloric?

we have reason to believe that caloric is
n in its nature; but this term is necessary,
e there exist in all bodies two portions of
, very distinct from each other.*
are these two portions of caloric distinguish-

one is called *sensible* heat, or free caloric;
er *latent* heat, or combined caloric.†

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bstances produces an intense cold. But the cause of
cts is easily explained. Whenever substances become
ndensed by mixture, heat is evolved; when they ex-
ld is produced; or, in other words, the compound has

What do you mean by free or sensible caloric?

Sensible caloric is the matter of heat disengaged from other bodies, or, if united, not *chemically* united with them.*

What is latent caloric?

Latent caloric is that portion of the matter of heat which makes no *sensible* addition to the temperature of the bodies in which it exists.†

What substances contain latent caloric?

Caloric in a latent state exists in all substances that we are acquainted with.‡

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placed in the open air, or under a large chimney to prevent any accident from the sudden combustion.

The reverse of this may be shown by hanging a pan of snow over a large fire. The snow will receive a great accession of caloric from the fire without being at all sensibly warmer. The caloric, as it enters the snow, becomes chemically combined with it, and the fire will not in the least alter its temperature, till the *whole* becomes fluid.

* Some writers have called the matter of heat when in this state *interposed* caloric.

† We owe to Dr. Black the discovery of *latent* heat. The train of thought and series of experiments which convinced him of this fact, may be seen amply detailed in the preface to his Lectures. "By this discovery we now see (as his editor expresses it) heat susceptible of fixation—of being accumulated in bodies, and, as it were, laid by till we have occasion for it; and are as certain of getting the stored-up heat, as we are certain of getting out of our drawers the things we laid up in them."—Black's Lectures, by Robison. He might have added, that whenever caloric quits its latent state, how long soever it may have lain dormant and inactive, it always resumes its proper qualities and character, and affects the thermometer and the sense of feeling as if it had never been latent.

‡ Caloric pervades all bodies: this is not the case with any other substance we know of—not even light. It lies hid in every thing around us. It is a substance which we are ever in want of; it is therefore deposited on every side, and is ready for every exigency.

ll substances contain the same quantity of la-
oric?

caloric combines* with different substances
different proportions.

language do chemists make use of to ex-
e difference in this respect?

body is said to have a greater *capacity* for
than another.†

s capacity for caloric uniformly the same in
e bodies?

same bodies have at all times the same ca-
for caloric, unless some change takes place
tate‡ of those bodies.

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ic, as it penetrates bodies, frequently forms a chemical
ion with them, and becomes essential to their compo-
his is always the case when a solid is converted to a

Can you adduce instances of a change of this kind?

When gaseous substances become liquid, or liquid substances become solid, they lose in a great measure their capacity for caloric: accordingly, when solid bodies become liquid or gaseous, their capacity for caloric is proportionately increased.*

If muriate of ammonia be dissolved in hot water, the temperature of the water will be found to be much lowered by the solution of the salt. When the salt takes again a solid form by crystallization, it will part with the caloric which it combined with in the act of solution, and a rise of temperature will be the consequence. The cold which is produced by the solution of this and other crystallized salts, is owing no doubt to the water, which was combined with them in a state of solidity, suddenly taking a liquid form, and absorbing caloric to preserve it in a state of fluidity.

If when the air is at 22° we expose to it a quantity of water in a tall glass, with a thermometer in it and covered, the water gradually cools down to 22° without freezing, though 10° below the freezing point. Things being in this situation, if the water be shaken, part of it instantly freezes into a spongy mass, and the temperature of the whole rises to the freezing point; so that the water has acquired 10° of caloric in an instant. Now whence came these 10°? Is it not evident that it must come from that part of the water which was frozen, and consequently that water in the act of freezing gives out caloric?—Dr. Black. Water in a solid state has less capacity for caloric, than it has when in a state of fluidity, although it then occupies a greater space.

The evolution of caloric which is occasioned by the combination of the condensable gases with water during several kinds of distillation, must be very familiar to those who have been accustomed to superintend chemical operations. In some cases, this evolution of caloric is so considerable as to raise ice-cold water almost to the state of ebullition. But there is a singular exception in the combination of oxygenized muriatic acid gas with a solution of potass. Whenever I have conducted this operation, I have not failed to notice, that though a large quantity of gas is absorbed by the liquid, very little caloric is evolved. The caloric doubtless forms a component part of the salt, and contributes to those powerful effects which are produced whenever this salt is deflagrated with inflammable substances.

* The freezing of water, and the cooling of melted lead,

does this property of bodies operate?

never a body has its capacity for caloric
ıcreased, it requires a larger portion of the
of heat to raise it to a given temperature,
nother body does which has a less capacity
ric.*

you exemplify this curious property of

qual quantities, by weight, of water and
y, cooled down to the same point, be af-
ls separately heated to the heat of boiling
the water will be found to have required
than three times the quantity of caloric

adduced as familiar examples of the former; and the

that the mercury did to bring it to that temperature.*

What term is made use of to denote the quantity of caloric thus required?

The portion of caloric necessary to raise a body to any given temperature is called the *specific* caloric of that body.†

Is there any method of ascertaining the specific caloric of different bodies, and comparing the relative capacity of each for caloric?

An instrument called a *calorimeter*‡ is used

* This property may be shown more readily by the following experiments:—Take 1lb. of water at 100°, and mix it with 1lb. of water heated to 200°, the mixture will be found to give the exact mean temperature of 150°; but 1lb. of mercury at 100°, and 1lb. of water at 200°, will produce a heat much higher than the mean temperature: mercury has not therefore so great a *capacity* for caloric as water.

A metal plunged into an equal weight of water of a higher temperature, gains more degrees of thermometric heat than the water loses; and this takes place, in different proportions, for each species of metal.—Berthollet.

Whenever two different kinds of substances of different temperatures are mixed, the capacity of each for caloric may be known by observing the temperature of the mixture: for the capacity of each will be in the inverse ratio of the change of temperature. But it is necessary, in order to justify this calculation, as Fourcroy has remarked, that the bodies themselves should not act chemically upon each other; and it is also necessary to prevent a portion of their caloric from being carried off by the vessels in which the experiment is made.

† This term is always used in a *comparative* sense, expressive of the relative portions of caloric contained in equal weights or measures of different bodies at the same temperature, or the comparative quantity of caloric which can produce the same effect. Thus, if the specific caloric of mercury be said to be 1, that of water may be said to be 3, as noticed in an experiment just related.

‡ The calorimeter was first suggested by M. Laplace, and contrived by Lavoisier. A drawing of the machine with an accurate description of it, may be seen in Lavoisier's Elements.

for this purpose. The substances to be tried are heated to the same temperature, and then placed in this machine surrounded with ice.* By observing how much ice each of them melts in cooling down to a given point, the specific caloric which each of them contained is determined.†

What do you call the instrument which is in common use to measure the temperature of bodies?

It is called a thermometer.‡ It consists of a glass tube containing a portion of mercury, with

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Though this instrument be capable of measuring what is called the *specific* caloric of bodies, no method has yet been discovered of ascertaining the *absolute* quantity which bodies contain. It is therefore unknown at what point a thermometer would stand, if it were plunged into a substance entirely deprived of caloric. According to the experiments and calculations of Crawford, Irvine, and others, the real zero is, probably, at least 1200 degrees below the freezing point of water.

* Ice has the property of absorbing all the caloric with which it comes in contact, and communicates no part of it to the surrounding bodies till the whole of the ice is melted; therefore the specific caloric of bodies may be calculated by its means.

† Sir Isaac Newton talks of boiling water being three times as hot as the blood in the human body. He imagined the freezing point to be the real zero, below which there was no heat. Later experiments have shown that substances may be cooled many degrees below the freezing point on Fahrenheit's scale. At Kamtschatka the atmosphere has been known to be 40 degrees colder than the zero of our thermometers.

‡ The thermometer was invented by Sanctorius, an Italian physician, about the beginning of the 17th century; but it was improved, and rendered useful, by Mr. Boyle and Sir Isaac Newton.

Thermometers are made by putting mercury into small glass tubes with bulbs, and heating these bulbs till the mercury boils. This ebullition exhausts the tubes of air, and they are hermetically sealed while the mercury is boiling; which preserves the vacuum. They are afterwards graduated by a correct scale.

Thermometers filled with alcohol are useful for ascertaining

a graduated plate annexed to it. The tube is hermetically sealed, to preserve the metal from the pressure of the atmosphere.*

Do you understand how a thermometer is affected by the temperature of bodies?

When a thermometer is brought in contact with any substance, the mercury expands or contracts till it acquires the same temperature; and the height at which the mercury then stands in the tube, indicates the exact temperature of the substance to which it has been applied.†

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very low temperatures in which mercury would be frozen,—as alcohol preserves its fluidity in the most intense colds that have ever been observed.

For very delicate experiments *air* thermometers are used, in which, as the air is expanded or contracted, a coloured liquor is made to fall or rise, which marks the degree of expansion, and consequently the variation of temperature. They are called thermoscopes.

* Though mercury has a capacity for caloric inferior to that of many liquids, it has such an attraction for it that it absorbs sufficient to keep it in a fluid state in the common heat of our atmosphere. Owing to this affinity it expands very readily by every addition of the matter of heat. It is also equally affected by equal increments of heat at every temperature between its freezing and boiling points; which is not the case with some other fluids, such as water, ardent spirit, &c.; hence it is the most proper substance for thermometers.

To measure the degrees of heat in high temperatures, Mr. Wedgwood contrived a very useful instrument which he called a pyrometer, including a range of nearly 32,000 degrees of Fahrenheit; a description of which may be seen in the 72d volume of the Philosophical Transactions. Since Mr Wedgwood's death, the method of making the pieces of clay for these pyrometers has been lost.

† Fahrenheit's thermometer is universally used in this kingdom. In it the range between the freezing and boiling points of water is divided into 180°; and as the greatest possible de-

*Will the thermometer show the quantity of caloric in all bodies?**

No: it will not show that portion which is latent, or chemically combined with any body: for instance, fluids require a certain portion of caloric to keep them in a state of fluidity; which portion is not indicated by the thermometer.†

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gree of cold was supposed to be that produced by mixing snow and muriate of soda, that was made the zero; thus the freezing point became 32°, and the boiling point 212°.

The centigrade thermometer of modern France, places the zero at the freezing point, and divides the range between it and the boiling point into 100°. This has long been used in Sweden under the name of Celsius's thermometer.

Reaumur's thermometer, which was formerly used in France, divides the space between the freezing and boiling of water into 80°, and places the zero, like the centigrade thermometer, at the freezing point.

De Lisle's thermometer is used in Russia. The graduation begins at the boiling point, and increases towards the freezing point. The boiling point is marked 0, and the freezing point 150°.

In Wedgwood's pyrometer the zero corresponds with 1077° of Fahrenheit's, each degree of which is equal to 130° of Fahrenheit. Therefore 180° F. = 100° C. = 80° R. = 150° D. L. = $\frac{48}{77}$ W.

For an easy method of reducing the degrees of one thermometer to the scale of another, consult Dr. Duncan's Elements of Pharmacy; or Lavoisier's Elements of Chemistry, p. 560, fourth edition. A table of temperatures, according to the different thermometers, at the end of this volume, will enable a person to form a tolerably correct idea of the difference there is in the scales of each.

* The property which we call the temperature of bodies does not show the measure of their caloric, but merely the degree of dilatation, which the caloric they contain in a disengaged state is capable of producing in the substance of which the thermometers are formed.

† Every substance requires its own quantity of caloric to raise it to a given temperature; but when raised to that tempera-

Is the thermometer, then, of no use in ascertaining the temperature of fluids?

Yes: all fluids operate upon the thermometer in the same manner as solids; for, whatever sensible caloric be contained in any liquid, that portion is accurately shown by the thermometer.*

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ture, every *further* addition of caloric is precisely shown by the thermometer. See Additional Notes, No. 4 and 36

If a quantity of snow be placed in a basin before a fire, and a thermometer be plunged in it, the thermometer will stand at 32°: if the thermometer be removed, and the snow suffered to remain before the fire some time longer, and then tried by the thermometer, it will still indicate the same temperature, though it has all along been receiving an accession of caloric; but the moment that the *whole* of the snow is melted the thermometer will begin to rise. In like manner, suppose a piece of ice cooled 20° below the freezing point, be exposed to a hot fire with a thermometer stuck in it; the thermometer will rise very uniformly till it comes to the freezing point 32°, and there make a full stop till the ice is all liquefied, as though the fire had *lost its faculty of heating*: but the instant that all the ice is melted, the thermometer *will begin to rise* again, and will continue to rise gradually till the water becomes heated to 212°, the boiling point. See Additional Notes, No. 4. These experiments show that the heat which snow and ice receive while melting, is necessary to give them fluidity, though it does not increase their temperature; and that ice contains much less absolute caloric than water at the same temperature. Were this not the case, all cold countries would be subject to dreadful inundations; for, whenever the atmosphere became warmer than 32°, the ice and snow would be melted *in an instant*, and the sudden deluge of water would sweep down every thing before it. It is pleasing to observe how careful the great Author of nature has been in providing for every exigency. To this goodness every clime and every season bear testimony:

"The tokens of his friendly care
Open, and crown, and close the year."

* Nature is uniform in all her results; for, if we plunge a thermometer ever so often into boiling water, it will always stand at the same point, provided the pressure of the atmosphere be the same. Melting snow will always show the same

at do you call that portion of caloric which is
ssary part of fluids?
s called the caloric of fluidity; but different
require different portions of it to preserve
in the state of fluids.*
at are the effects of caloric upon bodies?
general effects of caloric are to increase
ulk of the substances with which it unites,

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upon the thermometer, in whatever state the atmosphere

n tubes of glass mercurial columns rise
Or sink, obedient to th' incumbent skies;
Or, as they touch the figur'd scale, repeat
The nice gradations of circumfluent heat." DARWIN.

ject is further elucidated in Additional Notes, No. 36.

and to render them specifically lighter than they were before;* but in whatever quantity it is accumulated in bodies, it never adds to their absolute weight.

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compared with that of exciting heat. No one that we read of has ever yet been able to sink the temperature of any substance below—90° of Fahrenheit, or 122 below the freezing point of water; but Mr. Wedgwood constructed an air furnace in which he raised a heat equal to 135 degrees of his pyrometer, or 25127° of Fahrenheit; and by means of oxygen gas, more intense heats than even this have been produced.

* In order to be convinced that solids increase in bulk by combination with caloric, procure a piece of iron wire of an exact length, to slip lengthways within a ring, or within some metallic box: then if the wire be heated it will be found increased in length so as not to pass through the ring or box.

From the experiments of General Roy, in the 75th volume of the Philosophical Transactions, it appears that the expansion of a steel pendulum of a clock is such, that every four degrees of the thermometer will cause a variation of a second per day; and that the difference between the going of a clock in summer and winter will be about six seconds per day, or one minute in *ten* days, owing to the metallic pendulum varying in length with *every change of temperature*. A knowledge of this circumstance gave rise to Harrison's *self-regulating time-piece*, which, by the different expansion of *different* metals, accommodates its movements to every change of season or climate.

The expansion which heat gives to liquids may be shown by that of the spirits in a spirit thermometer: or fill a Florence flask with water to about the middle of the neck, mark the place to which it rises, and then immerse it in boiling water; when it will be seen to expand in the glass till it nearly runs over the neck of the flask.

The effect of heat on atmospheric air has been shown in page 43. The converse of this (viz. that the denser bodies are, the less caloric they contain,) may be exemplified thus:—Add one measure of water to four measures of sulphuric acid, and the temperature will rise to 300°, which is 68° above boiling water. If the mixture be now measured it will be found to measure less than it did; consequently it must have become much denser than the medium of the two separate liquors. If 28 measures of water be mixed with four measures of sulphuric acid, only 29 measures of mixture will be produced instead of 32.

The best collection of facts respecting the expansion of *accu-*

What are the particular effects of caloric on bodies?

It favours the solution of salts,* and promotes the union of many substances.† In other cases it serves to separate bodies already united;‡ so that in the hands of chemists it is the most useful and powerful agent we are acquainted with.§

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by heat, will be found in a memoir by Dr. Rittenhouse, in the Transactions of the American Philosophical Society.

Some bodies are much more dilatable by heat than others; thus iron is more dilatable than wood, and wood is more dilatable than a stone. Of the metals, platina dilates the least, and lead and zinc the most, by increase of temperature.

* Put two ounces of sulphate of soda (Glauber's salt,) in powder, into a tea-cup of cold water, stirring them together, and the water will dissolve only a portion of it; but if heat be applied, the whole will be dissolved. If the liquor be left to cool, the salt will be seen to shoot into crystals. This little experiment will have its use as an example of crystallization.

† Sulphur and mercury may be mixed without any apparent change; but if caloric be added, they combine so intimately as to form vermilion. Charcoal seems to have no attraction for oxygen in the atmospheric temperature, but if heated it unites to it with great eagerness.

‡ This is the case in distillation, whereby the most subtil parts of a compound body are dissolved by caloric, and separated from the mass in the state of gas or vapour. Every kind of distillation may be performed in a common retort, with common receivers attached to it. For strong heats, Wedgwood's retorts are preferable to glass. Some important directions for the conducting of different kinds of distillation may be seen in a paper of the thirteenth volume of the Repertory of Arts, which gives a very particular account of the management of these processes at Petersburgh.

Caloric also promotes the decomposition of bodies, by reason of its counteracting the attraction of cohesion which exists in all bodies.

§ For a more particular explanation of the effects of caloric in chemical processes, consult the article *Repulsion* in chapter xiii.

Mr. Watt mentions a strong analogy between *solution* and *fusion*: thus ice and soda have no more action on each other

Can you recollect any other effect that caloric has upon bodies?

It is the cause of fluidity in all substances which are capable of becoming fluid,* from the heaviest metal to the lightest gas.†

How does caloric act upon hard bodies to convert them into fluids?

It insinuates itself among their particles, and invariably separates them in some measure from each other.‡ Thus ice is converted into wa-

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than soda and silex; but raise the temperature of the ice, and it unites to the soda. A sufficient increase of temperature will unite the silex also to the soda. Potass and silex if mixed have no action whatever on each other; but if submitted to a great heat the potass melts, and attracts the silex, which melts with it into a substance that may be dissolved in water; or, if the silex be in proper proportion, the compound will be glass.

It is owing to the effect of caloric in promoting solutions, that *sea-water in the torrid zone* contains more salt than sea-water in the temperate and *frigid zones*.

* Let it be remembered that all fluids are formed from solids by an addition of caloric; and that, by abstracting this caloric, solids would be produced.

† For an account of the expansion of gaseous bodies by heat, see a detail of Mr. Dalton's experiments in the 5th volume of the Manchester Memoirs, p. 595; and in several papers in Nicholson's Journal. For a method of estimating the changes of volume in gases, consult Sir H. Davy's memoir in the Journals of the Royal Institution.

The expansion of volatile bodies by heat may be shown by the following experiment: Put a little ether into a small retort, tie a bladder to the beak of it, and hold the retort over a lamp. The ether will quickly boil, and the gas which arises from it will soon occupy the bladder and distend it to its full size. If the bladder be then held in water, the gas will be condensed by the loss of its heat, and the bladder will collapse. In order for this experiment to succeed, it is necessary previously to warm the bladder to 80 or 90 degrees, to prevent the gas from being condensed in the first instance.

‡ From this general effect upon bodies, caloric has been con-

ter, and by a further portion of caloric into steam.*

How are those substances distinguished which are capable of being thus rendered fluid by caloric?

We have reason to believe that every solid substance on the face of the earth might be converted to a fluid, or even a gas, were it submitted to the action of a very high temperature in peculiar circumstances.†

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sidered as the only agent in insensible repulsion. It has been called the *repulsive power*, which constantly acts in opposition to the power of attraction, or chemical affinity.

* Though the temperature of steam be no more than that of boiling water, or 212°, yet it has been demonstrated by some very ingenious experiments of Mr. Watt, that it contains near 1000° more caloric; and that this keeps it in the form of steam. Here the caloric must be in a state of chemical combination with the water, or it would be indicated by the thermometer. It is owing to this principle (viz. the necessity of a large quantity of caloric being combined with fluids, to convert them into vapour or gas,) that profuse perspiration is so cooling to labouring men, and that all evaporation produces cold. A person might be frozen to death in summer by being repeatedly sprinkled with ether. See Additional Notes, No. 36.

In Spain this principle is so well understood, that every family is provided with a utensil for cooling water or wine by *evaporation*. It is merely a piece of very porous earthenware, which they fill with water; and as a small quantity is perpetually oozing through every part of the vessel, a constant evaporation from the outside is kept up, which cools the water within. The vessels are called acarrazas, and may now be had at the china-shops in London and elsewhere.

"In India and China the wealthy have their rooms open on all sides, the roof being supported on pillars, and the intervals hung with curtains. Servants without doors scatter water on these curtains continually; its evaporation absorbs a vast deal of heat, and makes the apartments cool and refreshing." Dr. Black.

† The late experiments of Sir James Hall have thrown considerable light upon this subject. It appears that many substances which were deemed infusible, were so only in consequence of the decomposition they suffered in the usual way in

You say the sun is the great source of caloric: how is caloric transmitted from the sun to us?

Caloric is transmitted to us accompanied with light: both are perpetually thrown off from that immense body with astonishing velocity, in every direction.*

If caloric passes with such celerity, how is it retained by those substances which receive it?

It is retained by its affinity for those bodies,† or rather their mutual affinity for each other.

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which they were submitted to the action of caloric; but by means of a pressure sufficiently strong to prevent the escape of the volatile parts of the substance, such as the carbonic acid from calcareous earth, &c. he succeeded in fusing limestone, chalk, marble, and even common coal. These effects were produced, in several instances, at a temperature much lower than would have been imagined. See Sir James's very interesting papers in the Edinburgh Philosophical Transactions.

* Since the discoveries of Dr. Herschel, we have reason to *believe the sun to be an opaque body, probably a habitable world; and that the light and heat we receive from it are owing to an atmosphere which it has, of elastic fluids of a phosphorescent nature, by the decomposition of which, light and heat are evolved.* (Philosophical Transactions 1801, p. 265.) Aristotle conjectured that the sun was not a body of fire. Pursuits of Literature, 2d edition, part iv. p. 96.

"Hail to that orb, from whose rich fountain flow
Beams that illume and glad the world below!
Unseen by thee, had Nature mourn'd;
Nor sable Æthiop cheek adorn'd;
Pale Night had spread her spectred reign,
And death-like horror rul'd the scene."

DR. WALCOTT

See an interesting paper on the nature and construction of the sun and fixed stars, in Philosophical Transactions for 1794.

When we require a very intense heat, it is procured by collecting the sun's rays by means of a double convex lens, or a concave mirror. This way of administering heat is particularly useful in operations on the gases.

† As caloric (like light) moves at the rate of 200,000 miles

he chemical affinity of bodies for caloric in very strong?*

it is one of the weakest of all known af-

†

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ond, it never could be accumulated in any body, were tained by its *affinity* for that body. But for this re- force, it would pass through the body with the rapidity ing, and leave not a trace behind it.

ays of the sun seem to afford heat, only when they h an *opaque* substance, and not when they pass through rent one, as air or water; or when they are reflected te or polished one. The air is not heated immediately ays of the sun passing through it; but on their meeting opaque body, as the earth for instance, heat is elicited, ence gradually communicated to the surrounding atmo- Hence, the further we remove from the earth's sur- greater is the degree of cold.

Swiss peasants, when they want to sow their seed, spread oths on the surface of the snow, to absorb the sun's rays

How does this appear?

From the facility with which heated bodies part with their caloric to all surrounding bodies.*

Is this universally the case?

Yes: it seems to be one of the laws of nature, that heated bodies should give out *part* of their free caloric to the neighbouring bodies at a lower temperature, till the whole become of an equal degree of temperature.†

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* The facility with which caloric passes from one body to another may be owing to the repulsion which is known to exist among the particles of caloric. This repulsion gives it a tendency to fly off in every direction.

Count Rumford has asserted that fluids are non-conductors of heat; but Mr. Murray of Edinburgh has demonstrated the contrary by experiment. See his papers in Nicholson's Journal, vol. i. 8vo, 165—241.

The motion of caloric through bodies is of two kinds: through *some bodies it moves* with the same rapidity as through free space; through *other bodies it moves* with a remarkably slow motion. In the first case it is said to be *transmitted* through the body, in the latter *conducted* through it. For particulars consult Dr. Thomson's paper on the motion of caloric. vol. i. 310.

† Some bodies give out their superabundant caloric much sooner than others. Iron is a quicker conductor of caloric than glass, and glass is a better conductor than wood. Hence the use of wooden handles to metallic tea-pots and other utensils.

I take a piece of iron in one hand, and a piece of wood in the other; the iron feels cold, the wood warmer, though the thermometer shows that their temperature is the same. How is this? The iron has a stronger affinity for caloric than wood, and conducts it from the hand much swifter than the wood, and hence gives me a more lively sense of cold.

Some of the earths are very slow conductors of heat. Sand is eminently so. "The red-hot balls, employed by the garrison of Gibraltar to destroy the Spanish floating batteries, were carried from the furnace to the bastions in *wooden* barrows with only a layer of sand interposed; and this was found sufficient

me an instance of the operation of this law
re.

n the temperature of the atmosphere is
d below 32°, water gives out its superabun-
aloric by degrees, till at length the cold

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nt the balls, though in a high state of incandescence,
ing fire to the wood." Tilloch.
ecessity of one body being endowed with a greater
conduct caloric than another, is apparent in many in-
but perhaps the nature of snow in this respect renders
e important service than any other substance. Owing
istance of this globe from the sun, and to the vast
s of ice at the poles, the atmosphere over a large por-
he earth is at times reduced to so low a temperature,
re it not for a wise provision of nature, all vegetable
be destroyed. Caloric has always a tendency to equili-
herefore, if the temperature of the air be lowered, the
ls in proportion; but, when the atmosphere is reduced

atmosphere robs it of its caloric of fluidity also, and it becomes ice.*

If water be changed into ice by parting with its caloric, how comes it to pass that ice swims upon the surface of water?

Because, by the change which it undergoes, it becomes specifically lighter than the subjacent water.†

Did you not say that all substances become more dense by the loss of caloric?

They usually do; but the freezing of water is

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which it is applied." Notes on Fourcroy, vol. i. page 173. For a further elucidation of this subject, consult Dr. Thomson's Chemistry, vol. i. page 335; and Philosophical Transactions for 1802, page 403.

* The quantity of heat given out in freezing, occasions the progress of congelation to be extremely slow. The constant emission of caloric from the freezing substances operates favourably; for thus the severity of the frost is mitigated, and its progress retarded. This accounts for its often feeling warmer after a great fall of snow. On the other hand, if the return of caloric to the frozen body of water were not equally slow, what sudden inundations would be occasioned, in those countries where large masses of ice are collected, at the first approach of summer! as has before been remarked. That the melting of ice produces cold, is seen in many operations. By melting ice with common salt, confectioners produce cold much greater than that of the original ice.

† Ice is lighter than water, owing to air-bubbles produced in the ice while freezing: but Monsieur de Mairan attributes the increase in the bulk of water in freezing to a different arrangement of its particles; ice being a crystallization composed of filaments, which are found to be uniformly joined at an angle of 60°, and by this disposition occupy a greater volume than if they were parallel. See Dr. Rees's Cyclopædia, article Ice; and Dr. Black's Lectures, vol. i.

That ice contains a large portion of air, may be seen by the following experiment. Drop small pieces of ice into a tall glass full of hot water; as the ice melts, bubbles of air will be seen to rise from it, and burst at the surface of the water.

ing *exception** to this general law of nature, a memorable instance of the wisdom and

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e are acquainted with a few other exceptions. Saline so- expand in cooling as crystallization takes place: and erfect castings of iron may be had than of almost any etal, in consequence of iron always enlarging as it cools, ng the most minute parts of the mould into which it poured when in a fluid state; but we know of no fluid a *maximum* of density like water, and that expands heated above or cooled below that temperature.

neral, all bodies, whether solid or fluid, contract their ons and become of more specific gravity in cooling. iom has been long known and acknowledged; but *water* remarkable and striking exception. Water as it cools 2° .5, instead of contracting and becoming of greater gravity, actually becomes increased in bulk, and its gravity continues to lessen as it cools. Count Rumford this fact some years ago in one of his early essays. His , if I mistake not, are accompanied with some ingeni- ulations, to which I refer the reader. Sir C. Blagden

provident care of the Almighty, when he established the laws of the universe.

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specifically heavier by the loss of its caloric. In winter, when the atmosphere became reduced to 32°, the water on the surface of our rivers would have sunk as it froze; another sheet of water would have froze immediately, and sunk also; the ultimate consequence of which would have been, that the beds of our rivers would have become repositories of immense masses of ice, which no subsequent summer could unbind; and the world would shortly have been converted into a frozen chaos. How admirable the wisdom, how skilful the contrivance, that, by subjecting water to a law contrary to what is observed by other fluids, the water as it freezes becomes specifically lighter, and, swimming upon the surface, performs an important service by preserving a vast body of caloric in the *subjacent* fluid from the effects of the surrounding cold, ready to receive its own accustomed quantity upon the first change of the atmosphere! I shall not regret having subjoined these remarks, should they but afford

"One ray of light in this terrene abode,
To prove to man the goodness of his God."

CHAPTER IV.

OF WATER.

HAT is water?

ter is a compound consisting of hydrogen
xygen.

ow many states do we find water?

four: solid or ice; liquid or water; vapour
am; and in a state of composition with other
s.

ich is the most simple state of water?

at of ice.

How do you define vapour?

Vapour is water, combined with a still greater quantity of caloric.*

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point,) cannot melt till it has absorbed 140° more of caloric. This is the cause of the extreme slowness of these operations. There can be no doubt, then, but water owes its fluidity to its latent caloric, and that its caloric of fluidity is 140°." Thomson's Chemistry, vol i. 365.

The advantages which we derive from the slowness of these operations, and the inconveniences we should have suffered had it been otherwise, are numerous and obvious. See notes page 83 and 93; and Additional Notes, No. 5.

* However long we boil a fluid, in an open vessel, we cannot make it in the smallest degree hotter than its boiling point. When arrived at this point, the vapour absorbs the heat, and carries it off as fast as it is generated. Yet, by continued heat, united with additional compression, both the expansibility and temperature of steam may be greatly increased; and some constructors of steam-engines have lately availed themselves of this property, to augment the power and diminish the expense. See note page 49; also Additional Notes, No. 3 and 4.

Those who have an air pump may easily see that water requires a vast portion of caloric to convert it into steam; for, if a cup of *hot* water be put under the receiver, and the pump be set to work, the water will soon begin to boil furiously, and the receiver will be covered with vapour. If the receiver be now taken off, the water will be found barely lukewarm, owing to the vapour having carried off the greatest part of its heat. Water, in being converted into vapour, combines with more than five times the quantity of caloric that is required to bring ice-cold water to a boiling heat, and occupies a space 800 times greater than it does when in the form of water.

Owing to the quantity of caloric that liquids require to convert them into vapour, all evaporation produces cold. It has been remarked before, that an animal might be frozen to death in the midst of summer, by repeatedly sprinkling ether upon him. Its evaporation would shortly carry off the whole of his vital heat. Water thrown on hot bodies acts in the same way; it becomes, in an instant, converted into vapour, and thus deprives these bodies of a great portion of the caloric they contain.

The most striking example, that I have seen, of the production of cold by rarefaction, is given by Dr. Wolfe in his account of the fountain of Hiero, at the mines of Chemnitz in Hungary. In this curious machine, of which he has given a plate, the air is

What are the properties of vapour?

Vapour, owing to the large quantity of caloric which is combined with it, takes a gaseous form, acquires great expansive force,* and a capability of supporting enormous weights;† whence it has become a useful and powerful agent for raising

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compressed by a ponderous column of water, 260 feet high; it therefore happens, that whenever the stop cock is opened, this compressed air rushes out with great vehemence, becoming immediately much expanded. The consequence of this sudden rarefaction is, that the moisture the air contained is not only precipitated, but congealed; a part of which falls down in a shower of snow, and the other part forms icicles, which adhere to the nosle of the cock. Philosophical Transactions, vol. iii.

* The expansive force of steam is found by experiment to be much greater than that of gunpowder.

Some volcanic eruptions and earthquakes, it is supposed, owe their terrible effects to this power of steam; the water of the sea finding its way to subterraneous fires. See an account of the dreadful effects of the earthquake at Catania, in the notes to Madame de Genlis's Tales of the Castle, vol. ii. 241; or in Sir William Hamilton's splendid Survey of the two Sicilies.

In boiling oil, the workmen are very careful to prevent any water coming near it; for a single drop coming among it would instantly, by the excessive heat of the oil, be converted into vapour, and would force part of the oil over the sides of the boiler.

It is to the expansive force of steam that the well-known motion in water called boiling, is to be ascribed. The vapour is first formed at the bottom of the vessel, and, passing through the water, causes that motion in it which we call ebullition.

† The invention of the steam-engine was a vast acquisition to the arts. There is reason to believe that, in time, steam may be applied to many useful purposes, of which at present we have no idea. In America vessels are already navigated by steam.

"Soon shall thy arm, unconquer'd steam! afar
Drag the slow barge, or drive the rapid car;
Or on wide waving wings expanded bear
The flying chariot through the fields of air."—Darwin.

The steam-engine, approaching to the nature of a *perpetuum mobile*, or rather an animal, is incapable of lassitude; it procures

water from deep pits, and for other important purposes.*

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for us coals; it works metals; moves machines; and is certainly the noblest drudge that was ever employed by the hand of art. Thus we "put a hook in the nose of the leviathan; play with him as with a child; and take him for a servant for ever:" thus we subdue nature, and derive aid from the elements of earthquakes. Analytical Review.

The steam-engine is brought to such perfection, that one bushel of coals will raise 8,000 hogsheads of water ten feet high, and do the work of ten horses. Where there is no waste of steam, this work may be performed continually with the consumption of only one bushel of coals per hour. Some of the engine chambers in London are now fitted up with great taste, and are kept with the utmost neatness; in these one may spend hours without being annoyed by the escape of the most minute portion of steam.

Dr. Black calls the steam-engine, the master-piece of human skill, and the most valuable present that was ever made by philosophy to the arts.

* Steam is now employed in a vast variety of ways in the different manufactories of this kingdom. It is used with great economy of fuel in the dye-house of Mr. Desange, in Wheeler-street, Spital-fields. It should however be remembered that whenever it is intended to heat water by means of steam, the steam must not be thrown in upon its surface, but must be conducted to the *bottom* of the cold liquor before it be disengaged, or the effect will not be produced, water not having the power of conducting heat *downwards*. Hence some of the deepest recesses of the sea, even in the torrid zone, are perpetually covered with ice.

Messrs. Gott and Co. of Leeds, boil 30 large coppers by the steam of one boiler. It is employed elsewhere in drying malt, linen, coffee, paper, &c. and might be used with peculiar advantage in drying gunpowder. Dr. Black remarks, that steam is the most faithful carrier of heat that can be conceived, as it will deposite it only on such bodies as are colder than 212°.

Water heated to 220 degrees or upwards is found to be very effectual in bleaching linen goods. This method is coming into practice in the North of England. I am told that the necessary pressure is given by means of large chambers constructed of massy stone; and that in these chambers the linen is submitted to the action of the condensed steam.

In what proportions are oxygen and hydrogen in water?*

Water is composed of 85 parts by weight of oxygen, and 15 of hydrogen,† in every 100 parts of the fluid.

How is it known that water is a compound substance?‡

Several methods have been contrived by chemists whereby water may be decomposed, and

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* Both these terms are derived from the Greek language; the former signifies to *generate acids*, the latter to *generate water*.

† Hydrogen appears capable of uniting with oxygen only in *one* proportion, and water is the result of the composition.

Of all the known substances, there is not any of which an equal weight can combine with so large a portion of oxygen, covering at the same time its characteristic properties, as hydrogen; but losing also all those which characterize itself:—it requires only 15 of hydrogen to saturate nearly 85 parts of oxygen to this point, that is, to form water.

As water does not permit any property of oxygen or hydrogen to be perceived, it may be concluded that these two substances are combined at the point at which the reciprocal affinity exercises the greatest effect; and that they are in a state which may be compared with that of a neutral salt, in which the acid and alkaline properties have equally become latent. Berthollet.

‡ This was discovered by Mr. Cavendish, in the year 1781. Dr. Priestley had previously combined the two gases by combustion; but Mr. Cavendish was the first who drew the proper conclusion from the Doctor's experiment. The benefit which the world has derived from the labours and communications of such men is incalculable. "Nature," says an elegant French writer, "in order to unite mankind by a reciprocal communication of knowledge, has given to each individual his particular ignorance; and has placed science as a common stock to render us necessary and interesting to each other."

From a passage in Virgil's Georgics, lib. ii. 325, one might imagine that the ancient chemists of Egypt had discovered the composition of water. See the notes in Darwin's Botanic Garden, book i. 136.

the exact proportion of its constituent parts ascertained.*

Do you know any of the methods of decomposing water?

Yes, there are several: it may be done by passing it through a tube over red-hot charcoal,† by passing repeated electrical shocks through it, and also by means of the galvanic apparatus.‡

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* A history of the discovery of the composition and decomposition of water, with the curious facts relating thereto, may be seen detailed in a familiar and pleasing manner, by Mr. John Thomson, in his valuable Notes on Fourcroy, vol. i. 237, &c. The operation of electricity or galvanism, in uniting the two gases to form water, is explained by Mr. Murray, with great perspicuity, in the notes to his System of Chemistry, vol. i. p. 25.

† "Water cannot be decomposed without a combustible body," or the agency of electricity or galvanism, "as the hydrogen requires a very large dose of caloric to put it in a gaseous state. This appears from the lightness of hydrogen gas compared with water. A cubic foot of water weighs 62½ pounds, whereas a cubic foot of hydrogen gas weighs, on an average, only 61 grains." See Additional Notes, No. 13.

‡ When two wires from the opposite extremities of a galvanic battery are placed in a tube containing water, so that they are distant from each other ¼ or ½ an inch, a stream of gas issues from each wire—from the positive wire, oxygen—from the negative, hydrogen gas; and these are in the proportions which when exploded, either by galvanism or electricity, reform water. See more on this subject in Murray's Chemistry, vol. ii. p. 172.

Some French aëronauts decomposed water by the galvanic pile at an elevation of near three thousand metres from the earth. Phil. Mag. vol. xix. 374.

The decomposition of water by electricity or galvanism, which produces an intense heat, seems to prove that there is a degree of temperature at which water cannot exist, but in which it is reduced to its two elements. Berthollet.

Water is often partially decomposed by being kept for a long time in casks, especially on long voyages. The wood combines with its elements, forming, amongst other impurities, carburet-

Does nature decompose water in any of her operations?

Certainly, by many: particularly by means of every living vegetable; all vegetables having the power of decomposing water, by a secret operation peculiar to themselves.* Fish in general, and all cold-blooded amphibious animals, we have reason to think, are endowed also with the same faculty.†

For what purpose are vegetables endowed with this power of decomposing water?

They combine part of its hydrogen, as well as of its oxygen, with the carbon of the atmosphere and of the soil, to form the vegetable compounds oil,‡ wax,§ gum, resin, sugar, &c. while the

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ted hydrogen. Hence the disagreeable taste and smell which are observable in such water. If the cask be charred on the inside, it will not operate in this way.

* See the latter part of chap. ii. and Additional Notes, No. 18.

† Among other cases, we read of a fish that was kept three years in a vessel, and fed only with water, and that at last it became too large to live any longer in the vessel. Whence this increase of animal substance, if we deny it the power of decomposing water? Rondelet. de Piscibus, lib. i. cap 12.

‡ It should always be recollected that the oil found in vegetables is produced by this process of vegetation. The oils, bitumens, &c. in minerals, must all have had a vegetable origin.

In the dutchy of Modena, mineral oil is separated from bituminous coals by a natural subterranean distillation. The inhabitants of the district, by piercing the sides of a particular rock, at different distances from its summit, obtain oil of different kinds, thickening, and growing deeper-coloured, as the channels through which they flow approach to the surface of the earth. Bishop Watson.

§ In Louisiana and Pennsylvania, the *myrica* is cultivated

superfluous oxygen is abundantly evolved by the leaves;

> "Killing infectious damps, and the spent air
> Storing afresh with elemental life."

*Can you recapitulate what has hitherto been detailed of the nature of oxygen?**

Yes: oxygen is the basis of vital air, as well as one of the constituent parts of water; it is the chief support of life and heat; and performs an important part in most of the changes which take place in the mineral, vegetable, and animal kingdoms.†

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solely for the *wax* which it produces? In China, vegetable wax is extracted from plants by maceration in boiling water, and employed in the manufacture of candles.

Bees' wax is doubtless a vegetable product. The bees extract it unaltered from the leaves of trees, and other vegetables. They seem, however, to mix it with some of the pollen of flowers. The comb which these insects form with the wax, is a collection of hexagonal cells closely fitted to each other. It may be remarked that no other geometrical figure could have been chosen for them, that would have been equally capacious, without any loss of room; so that the operation of infinite wisdom is apparent even in the impression of that instinct whereby these little animals are directed to fabricate their cells in that particular form and in no other.

* Nature, in economizing the primary materials of the universe, has constituted *oxygen* the basis both of the atmosphere which surrounds the earth, and of the water which forms its seas and oceans.

> "For mark how oxygen with azote gas
> Plays round the globe in one aërial mass,
> Or, fus'd with hydrogen in ceaseless flow,
> Forms the wide waves which foam and roll below."

We see in this and other instances, by what simple means the most beneficial effects have been produced.

† Some idea may be formed of the importance of oxygen, by

it is hydrogen, the other constituent part of

rogen is the base of the gas which was
ly called inflammable air, and is, when in
riform state, the lightest of all ponderable
*

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g to the analysis which Lavoisier made of the materials
y for fermenting 100 pounds of sugar.

	lbs.		*lbs.*	*oz.*
ater	400	Oxygen of the water -	340	
gar	100	Ditto of the sugar - -	64	
ast	10	Ditto of the yeast - -	7	$12\frac{3}{4}$
	510		411	$12\frac{3}{4}$

Hydrogen of the water	60	0
Ditto of the sugar	8	0

Has any method been discovered of composing *water by a mixture of oxygen and hydrogen?*

Yes: there are several ways of doing this;* so that the composition of this fluid is now ascertained beyond all doubt.†

Do you know any of the methods which have been employed to form water by a mixture of its constituent parts?

Yes: if a mixture of oxygen and hydrogen

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* An ingenious and simple apparatus for the re-composition of water, has been invented by Mr. Cuthbertson. A drawing and description of it may be seen in Nicholson's Journal, vol. i. 4to, page 235.

† The decomposition of water and its subsequent re-formation may be shown by the following easy experiment: Add gradually one ounce of sulphuric acid to four ounces of water in a large phial containing a few iron filings. The temperature of the mixture will be so much raised by the union of the water with the acid, as to enable the iron to decompose a part of the water. If a hole be neatly made through a cork which fits the mouth of the phial, and a piece of tobacco-pipe with a very small orifice be fitted into it, and the whole cemented into the phial with a mixture of resin and bees' wax, the hydrogen gas as it is separated from the water will pass in a continued stream through the pipe, and may be set on fire by the flame of a candle brought in contact with it. The gas will continue to burn with a blue luminous flame, as long as the decomposition goes on. This shows that the gas is really hydrogen, and that it arises from the decomposition of the water.

That water may be re-formed by the combustion of this gas, may be shown by holding a glass bell over the flame of the gas: as the hydrogen burns it unites with the oxygen of the atmosphere, and the union of the two gases produces water, which will soon be seen to deposit itself like dew on the inside of the glass. *It is advisable to fold a cloth round the bottle to prevent any injury from the fragments of glass, in case of an explosion, which sometimes will happen during this experiment, if atmospheric air be left in the phial; or let the gas burn for a moment before the cork and pipe are fixed into the neck of the bottle.*

, in proper proportion, be fired, the inflam-
n will unite the bases of the two gases, with-
eparating the whole of their caloric, and
will be the product.*

here any reason to suppose that water is thus
l in any of the great operations of na-

: it is probable that the torrents of rain
generally accompany thunder storms, may
from a sudden combustion† of hydrogen and
n gases.‡

Lavoisier's Elements of Chemistry, a copper-plate print
xcellent apparatus for composing water may be seen, with
nd satisfactory description of the method of making use
See Additional Notes, No. 13.

How is the atmosphere furnished with this hydrogen gas?

Hydrogen is continually emanating from, and is the consequence of, every species of vegetable and animal decay or putrefaction; and it is also evolved from various mines, volcanoes, and other natural sources.*

What is the specific gravity of water?

A wine-pint measure of water weighs one pound;† consequently a cubic foot of water weighs about 1000 ounces, or 62½lbs. avoirdupois. It is 816 times heavier than atmospheric air.‡

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tion till ignited by electricity. The vulgar entertain strange conceits about this curious phenomenon of nature.

"Not so the man of philosophic eye
And inspect sage; the waving brightness he
Curious surveys, inquisitive to know
The causes and materials (yet unfix'd)
Of this appearance beautiful and new." THOMSON.

* Hydrogen gas is only one thirteenth of the weight of atmospheric air, and occupies a space fifteen hundred times greater than it possessed in its aqueous combination.

The ignis fatuus, or will-o-wisp, originates from decayed vegetables, and the decomposition of pyritic coals; it consists generally of hydrogen combined with carbon; and, perhaps, occasionally with phosphorus or sulphur.

"Thus heat evolv'd from some fermenting mass
Expands the kindling atoms into gas."

Dr. Shaw, in his Travels in Palestine, has given a curious account of an ignis fatuus which he observed there.

† It is very necessary for the student to bear in mind the specific gravity of water, because this is always taken for unity in the measure of the specific gravity of every other substance.

‡ This estimate is agreeable to the last experiments made by Sir Geo. Shuckburgh, when the barometer is at 30 inches, and the thermometer between 50° and 60°.

at change does water undergo in order to be ted into ice?

e atmosphere, when its temperature is suf- ly low, deprives the water of a certain por- of its caloric—crystallization then ensues, ıe water solidifies and becomes ice.*

at do you mean by crystallization?

crystallization is understood the concretion tain substances into regular forms, occasion- the loss of a portion of their caloric.

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ter in freezing crystallizes in filaments, which are uni- joined at an angle of 60 degrees.

been said that water may be purified from the putridity nay be contained in it by *freezing*; and that in such

To what substances is the term usually applied?

The term is generally applied to compound bodies of the saline kind, and to their separation in regular and peculiar figures, from the water in which they were dissolved.*

You have said that ice is the most simple state of water;—do you then imagine that water is naturally solid?

Underneath the poles water is eternally solid; there it is similar to the hardest rocks,† and may

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should in this instance be subjected to a law different from that of other substances which change from fluid to solid. For an account of this important deviation from a general law of nature, see the last notes in chap. iii.

It may be remarked, that though fresh water freezes when reduced to the temperature of 32°, sea water does not freeze till cooled down to 28.5°. Was not this designed by nature to keep the ocean open at all seasons, that there might be no impediment to that general intercourse among nations which tends so much to promote their civilization and refinement?

"For this the ship, in floating balance held,
By earth attracted and by seas repell'd,
Directs her devious track, through climes unknown,
That leads to every shore and every zone." FALCONER

* Crystallization is a kind of precipitation, in which the salt as it separates from the solvent assumes peculiar determinate forms. Mr. Smithson has shown that crystallization cannot take place while solution subsists, and that the only requisite for this operation is a freedom of motion in the masses which tend to unite. Phil. Trans. for 1803, page 27.

† There happen cracks at certain times in the ice mountain of Switzerland, which have shown the great thickness of the ice; some of these cracks have measured 300 or 400 ells deep. Near Hudson's Bay there are islands of ice which are immersed above 100 fathoms beneath the surface of the sea, and which measure three or four miles in circumference. Phil. Trans.

"There can be no doubt but that the quantity of ice at the

be formed by the chisel of the statuary, like stone.*

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north pole is the principal source of the coldness of our winters, and that it is brought hither by the regions of air blowing from the north."

"Where, for relentless months, continual night
Holds o'er the glittering waste her starry reign."

The ice at each pole of the earth forms an immense cupola, the arch of which extends some thousand miles over the continents; the thickness of which, beyond the 60th degree of latitude, is several hundred feet. Navigators have assigned to detached masses, which are met with floating at sea, an elevation of from 1500 to 1800 feet. See Ellis's Voyage to Hudson's Bay.

There can be no doubt but that the thickness of these cupolas of ice is much greater nearer the poles; for astronomy sometimes presents in the heavens so vast an image of them, that the rotundity of the earth seems to be considerably affected thereby. Captain Cook could never approach nearer the south pole, where there is no land, than the 70th degree of latitude; that is, no nearer than 1500 miles, though he had coasted round it for a whole summer; and it was only under favour of a bay that he was permitted to advance even so far. St. Pierre's Studies, vol. i. 129—132.

From a late memoir by Mons. Perron, there is reason to believe that these mountains of ice at the poles, which have hitherto impeded the progress of European navigators, have been detached from the depths of the sea to float at the surface. All the results of observations made by him and other navigators, concur in proving that the temperature of the sea decreases according to the depth; and that the deepest gulfs of the sea are continually covered with ice, even under the equator. A translation of this interesting memoir may be found in the 21st volume of the Philosophical Magazine.

* "It is related, that at the whimsical marriage of Prince Gallitzin, in 1739, the Russians applied ice to the same purposes as stone. A house consisting of two apartments was built with large blocks of ice; even the furniture of the rooms was made with ice; and the icy cannon, which were fired in honour of the day, performed their office more than once without bursting." Bishop Watson.—See Additional Notes, No. 17 and 55.

In the most northern part of the Russian territory, the cold

Is this great solidity of ice at the poles, owing to its being frozen in such large masses?

The great solidity of ice at the poles is occasioned by the very low temperature of the circumambient air:* for in very cold countries ice may be ground so fine as to be blown away by the wind, and will still be ice.

Is ice the only instance of water existing in a state of solidity?

No: water becomes still more solid in the composition called mortar and in cements, (see

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is sometimes sufficient to freeze mercury, or 72 degrees below the freezing point of water. It is so intense in some seasons, that the poor inhabitants cannot venture out of their miserable huts but at the hazard of their lives.

"There, through the prison of unbounded wilds,
Barr'd by the hand of Nature from escape,
Wide roams the Russian exile. Nought around
Strikes his *sad eye, but deserts lost in snow,*
And heavy loaded groves, and solid floods,
That stretch athwart the solitary vast
Their icy horrors to the frozen main."

See Additional Notes, No. 17.

* We need not look for any cause for the conversion of water into ice, but the loss of its caloric; for in the Grotto of Besançon water is frozen during the heats of summer. In this singular place the variation of the thermometer between winter and summer is very inconsiderable.

Though water be converted to ice by the loss of caloric, there is reason to suppose that ice, notwithstanding, contains more caloric than was disengaged between the state of vapour and that of congelation. See Berthollet's Statics, vol. i. 154.

I have been informed by some intelligent workers in iron and steel, that they have great difficulty in making tools hard enough to cut ice in extreme *cold* winters; and that in such seasons the workmen are under the necessity of having their instruments very frequently repaired.

ote on the properties of lime, chap. v.)
parted with more of its caloric in that
nation than it does in the act of freezing.*
t other instances are there of water taking
form?
er is also combined in a state of solidity in
, in crystals, in spars, in gems, and in all
e and earthy salts; to all of which sub-
s it imparts hardness, and to most of them
rency.†

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ugh water takes a solid form in its various combina-
ch as with lime, saline crystals, &c.; we know of no
of compressing it when in a fluid state. The Floren-
lemicians filled a globe of gold perfectly full of water,
nilted it to a very powerful press; but could not per-
t they were able to make it occupy less space than it

What are the general and more obvious advantages which we derive from water?

Water is a necessary beverage for man and other animals; is perpetually used as a solvent* for a great variety of solid bodies;† acts an important part in conveying nourishment to the vegetable world,‡ and giving salubrity to the atmospherical regions;§ and lastly, by its accumulation in the ocean,‖ affords a ready communication with

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separate it. In its combination with lime it becomes much more solid than when in the state of ice; which may be proved by direct experiment. Calcined plaster of Paris, in a pulverulent state, becomes quickly solid by mixing it with water. Saussure has proved that alumine, when mixed with water, retains a tenth of its weight of that fluid at a heat which would melt iron.

* It should be remembered, that all bodies which are soluble in water, form, during their solution, a chemical combination with the water, and that solutions in water are not mere mechanical mixtures.

† Water is not only employed as a solvent for many solid substances, but has important uses in a variety of compounds. Besides imparting solidity to the classes of salts, it gives energy to the action of many of the acids, and is even necessary in their formation. Muriatic acid and nitrous acid gases are condensed so as to form liquid acids, merely by their union with water.

‡ For an account of several modern experiments on the growth of vegetables in water, see Additional Notes, No. 67.

§ See note, chap. ii. page 67.

‖ Some late experiments of Mr. Harrop's, related in the fifth volume of the Philosophical Journal, render it probable that the ocean and other large bodies of water may have been designed by nature as reservoirs for supplying an increased population with the oxygen necessary for its consumption, and for producing a regular renovation of the atmosphere. The immense quantities of marine productions found at very great heights above the present level of the sea, seem to indicate that there has been a prodigious recession of the ocean. While water was conceived to be a simple and indestructible substance, in-

t countries; the whole of which evidently
es how provident the great AUTHOR of nature
been in his attentions to the comforts and
niences, as well as to the wants, of his nu-
is creatures.

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ble conjectures were afloat as to the channels which had
und for such an immense body of water. The new che-
octrines have afforded us a clue by which to unravel this
, and fresh motives for admiring the exquisite contri-
of the great Author of all things.

——————"That mighty hand
hat, ever busy, wheels the silent spheres,
orks in the secret deep, shoots, *steaming*, thence
e fair profusion that o'erspreads the spring."

his subject further investigated in the Additional Notes,

not resist making an extract from Mrs. Charlotte Smith's
ations on the Ocean: "There are people," she says,

CHAPTER V.

OF EARTHS.

WHAT are the principal characters of a simple earth?

The earths are incombustible bodies, and in general are unalterable in the fire. Till lately they were thought to be unsusceptible of decomposition;* are insoluble in water, or nearly so, when combined with carbonic acid;† and are of a specific gravity never exceeding five times that of water.

How many earths are there?

There are nine distinct earths known at present, viz. silex, alumine, zircone, glucine, yttria, barytes, strontian, lime, and magnesia.‡

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* Baron Born, many years ago, was of opinion that the earths were compound bodies. Sir Humphrey Davy has now succeeded in decomposing most of them; and from his experiments we have reason to suspect that they are all metallic oxides.

† Bergman classes all substances, except metals, with the earths, which require more than one thousand parts of water for their solution. We have, however, another test to distinguish them, when held in solution by acids, viz. the prussian alkali. Prussiate of potass, and indeed prussiates in general, have the property of precipitating all metallic oxides from their solutions; yet, excepting yttria, it has no effect on any of the earths.

‡ To a cursory observer the earths appear to be infinitely diversified; so much so, that he would probably think the different kinds are innumerable. However, notwithstanding the

Why are some of these earths called alkaline earths?

Barytes, strontian, and lime,* are called alkaline, because they agree with alkalies in taste, causticity, solubility in water, and in their effect on vegetable colours.† Magnesia agrees with the alkalies in the latter property only.

What is the nature of silex, and what are its chief properties?

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varied appearance of the earth under our feet, of that of the furrows of the field, and of the mountainous parts of the world, whose diversified strata present to our view substances of every texture and of every shade, the whole is composed of only nine primitive earths: and as three of these occur but seldom, the *variety* which is produced by the other *six* becomes the more remarkable. This may fairly be adduced as one instance of the infinite skill of the Deity, as it "bespeaks an artist master of his work, acquainted with his materials."

To give a still greater variety to the works of Nature, these earths are endowed with an affinity for acids and metallic oxides, whence arise the spars, gems, and precious stones of every colour and every species.

"The unfruitful rock itself, impregn'd by thee,
In dark retirement forms the lucid stone."

* Barytes, strontian, lime, and magnesia, are found in nature always combined with acids. None of the combinations are very hard, as either of them may be scratched with a knife. The acids which are found united by nature with these alkaline earths, are generally the carbonic, the sulphuric, the fluoric, the boracic, and the phosphoric.

† Barytes, strontian, and lime, differ from the alkalies, in their infusibility by fire, in forming insoluble compounds with carbonic acid, and in being insoluble in alcohol. As these are the common properties of the earths, we have sufficient reason to reject the proposal of some of the French chemists, who are desirous of transferring these substances from the earths to the class of alkalies.

SILEX,* or pure flint, is insoluble in water,† and in every acid except the fluoric; it endures the strongest heat without alteration;‡ but, when mixed with soda or potass, becomes fusible in a strong fire into glass. Its specific gravity is 2.65.

In what state is silex found native?

Silex is found in almost all solid mineral substances, particularly in gravel, sand, quartz, and

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* *Pure* silex may be procured for chemical experiment by fusing common flint stones with three or four times their weight of potash, dissolving the product in water, and then taking up the alkali by the addition of an acid, which will precipitate the silex, which is to be well washed for use. The siliceous stones should be previously heated red in a crucible, and plunged in that state into cold water. This will render them brittle, so that they may easily be reduced to powder before they are mixed with the potash.

Sir Humphrey Davy has not yet succeeded in exhibiting the base of this earth in a separate state, though from the result of his experiments, there is great reason to believe that silex, like the other earths, is a metallic oxide. *El. Ch. Phil.* part i. page 362.

† We cannot by any means dissolve silex in water:—Nature, however, by some wonderful and unknown process, contrives to dissolve it, even copiously, so as to form stalactites and other incrustations. In Iceland there is a boiling fountain which spouts water 90 feet in the air, and deposites in falling so great a quantity of siliceous earth, that it forms around its base a sort of solid cup, which surmounts and envelops it.—See note, p. 49. This earth has also been found in solution in the Bath waters, and in some other spring water.

‡ According to Saussure, quartz or silex may be fused by a heat equal to 4043° of Wedgwood; but this is a temperature so far above any heat that can be procured by common means, that I have not thought it necessary to alter the text. Mr. Hare also fused it by means of a stream of oxygen and hydrogen gases.

It is a curious fact, that if barytes be fused with this earth, the compound will be soluble in all the acids.

Sand sets into a less bulk when wet, and does not afterwards contract by heat. This property may be taken advantage of in constructing reverberatory furnaces, &c.

flint, of which it forms nearly the whole substance.* It is also the chief ingredient of those rocks which constitute the most bulky material of the solid parts of our globe.†

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* Dr. Kirwan, in his Geological Essays, relates, that about the year 1760 the emperor of Germany, being desirous to know the length of time necessary to complete a petrifaction, obtained leave from the Sultan to take up and examine one of the timbers that supported Trajan's bridge over the Danube, some miles below Belgrade. The outer part of this timber, to the depth of half an inch, was found to be converted to an *agate*; the inner parts were slightly petrified, and the central were still wood. The agate is a precious stone composed of silex and alumine, but chiefly silex.

Agate is brought from Germany in blocks. It is cut by means of diamond powder into leaves, for making caps for the pivots of mariners' needles to run in, and other purposes. Might it not be used advantageously for the balances of watches, instead of iron, which is liable to vary by magnetic influence and other causes?

† "A granite mountain, about 30 miles from the Cape of Good Hope, called the PEARL DIAMOND, *rises out* of the ground to the height of 400 feet, being half a mile in circumference, and formed of a single block of granite."—Parkinson's Organic Remains.

Silex also constitutes two thirds of the asbestus, so valued by the ancients for wrapping up the bodies of the dead before they were committed to the funeral pile. They discovered methods of drawing the fibres of the mineral into thread, and afterwards weaving it into cloth. In consequence of its incombustibility, it preserved the ashes of the body from mixing with those of the wood upon which it was laid to be burnt. The practice was, however, probably confined to the families of the opulent. So late as the year 1702 a funeral urn was discovered at Rome, in which were a scull and other remains of a human body, wrapped in a cloth of amianthus or flexible asbestus. The whole was deposited in the Vatican library.

This mineral might be manufactured into paper; and, for documents of great importance, it might, perhaps, be worth while to be at the expense of preparing this incombustible paper, and of writing upon it with indelible ink. The methods of making it into paper or cloth, and of preparing proper ink for writing upon it, may be seen in Dr. Rees's Cyclopædia. The mineral

What are the chief uses of silex?

Silex is the most durable article in the state of gravel for the formation of roads; it is a necessary ingredient in earthen-ware, porcelain, and cements; is the basis of glass,* and of all vitreous substances;† and is an indispensable article in many of our chemical furnaces and utensils.

What is the use of silex in glass-making?

Silex is the chief ingredient in glass. It is ren-

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is found in Corsica; in the isle of Elba; in Sweden; and in Cornwall and the isle of Anglesea, in England.

The Chinese form furnaces with this mineral. They grind it, mix it up with some kind of mucilage, and introduce it into moulds, the form and polish of which it assumes. These furnaces are very portable, and indestructible by fire. What kind of mucilage they employ is not known; but it is said that the mucilage of gum *adraganth* answers this purpose completely.

* The manufacture of glass was known very early; but glass perfectly transparent was reckoned so valuable, that Nero is said to have given a sum equal to 50,000*l.* for two glass cups with handles. When the excavations were made in the ancient city of Pompeii, which was buried by an irruption of Vesuvius A. D. 79, the windows of some of the houses were found glazed with a thick kind of glass, not transparent. In others isinglass was substituted, split into thin plates.—Miss Starke's Letters from Italy.

The best book on glass-making which I have seen, is an octavo volume, by H. Blancourt, with plates, 1699. But a scientific work, lately published in Paris by Loyzel, entitled "Essai sur l'Art de la Verrerie," is, I believe, the best modern work on this subject. It gives a detailed account of the different processes in this manufacture, and treats of each chemically.

The manufacturing of *pastes*, or artificial gems, is a branch of the art of glass-making. The basis of these is a very hard and pure silex, obtained by melting pounded quartz with an alkali, with the addition of borax, nitre, and oxide of lead, different metallic oxides being added to imitate the colour of the different gems.—See Journal de Physique, tom. xxviii. page 502.

† I would recommend to the perusal of the young reader, Fourcroy's account of the various uses of silex in vol. ii. of his System of Chemistry, page 190. It is beautifully written, and cannot fail to interest and instruct the pupil.

dered fusible by a due mixture of alkali, which acts as a flux to the silex, and renders the whole transparent.*

Are these the only articles necessary to form glass?

In Holland, and some other parts of Europe, glass is manufactured with alkali and sand only; but in England, flint-glass is made by a mixture of red lead† with those substances; which gives the glass great weight, and makes it more useful for all common purposes.

What are the chief properties of alumine?

ALUMINE, or pure clay, is soft to the touch; adhesive to the tongue; emits a peculiar odour

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* Glass cannot be made without great heat, as the alkali retains the last portions of carbonic acid and water with singular obstinacy, and it is only at a very high temperature that the alkali fuses, and then it prefers the silex; for it is one of the laws of nature, (to which there are few exceptions,) that, in order that two bodies may become *chemically* united, one of them must be in a state of fluidity.

† Metallic oxides have the property of making glass more fusible. The oxide of lead is serviceable in this way when mixed with glass. Plate and crown glass contain no lead, but the former has generally lime combined with it.

The common bottle glass is made with a large portion of the ashes of vegetables, or soap-boilers' waste ashes, instead of pure alkali. The portion of iron, which is generally found in vegetable substances, gives it the green colour.

For the best flint glass, rather more alkali is used than is necessary to flux the sand; and when the whole is in fusion, the fire is continued so as to volatilize the superabundant quantity. If an excess of alkali be left in the glass, it will attract water from the atmosphere, and in a short time assume a fluid state.

Professor Seigling, having left a bottle of *liquor silicum* undisturbed eight years, found transparent *rock crystal* formed in it, hard enough to give fire with steel. See an account of a similar result in Nicholson's Journal, vol. i. 217.

when moistened; forms a paste with water; will unite with most acids;* and acquires great hardness, and contracts in the fire.† Its specific gravity is 2.

In what state is alumine found native?

This earth acquired its name from its being the basis of alum;‡ it has also been called *argil*, as it it is the principal part of all clay;§ it is found in a state of crystallization in the sapphire, and is united to the oxides of iron in the ochres; it also forms a part of the precious stones.

What are the chief uses to which alumine has been applied?

Alumine in the state of *common clay* is em-

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* Alumine is soluble in every acid, and in solutions of the caustic fixed alkalies. Sir Humphrey Davy has made many attempts to decompose this earth; and though there are reasons to believe that he has succeeded in part, the experiments were not so decisive as they were with the other earths. Elem. Chem. Phil. page 355.

† Alumine is completely fusible *per se* into a very hard vitreous kind of substance, hard enough to scratch glass; but sufficient heat cannot be procured to effect its fusion without oxygen gas. Saussure found that it required 18.900° of Wedgwood to fuse it; but when mixed with certain proportions of silex and lime, it fuses readily.

‡ Pure alumine may be procured by decomposing common alum with carbonate of ammonia. It has not been found native in a state of purity any where, except at Halle in Germany.

§ Common clay is a mixture of alumine and silex. It frequently contains metallic oxides, chalk, and other earths. Alumine united to the oxides of iron, is plentifully procured in Staffordshire and Derbyshire; in which state it is called raddle, an article very useful in colour-making. Fullers' earth is alumine combined with very fine silex. It is owing to the affinity which alumine has for greasy substances, that this article is so useful in scouring cloth. Hence pipe-clay is frequently used for the same purpose.

ployed for various purposes, on account of its aptitude for moulding* into different forms,† and its property of hardening in the fire; such as for making bricks, earthen-ware, porcelain,‡ crucibles, &c. &c.

Is alumine employed in forming any chemical combinations?

Aluminous earth is employed in different combinations by the dyer and the calico-printer, as a mordant for fixing various colours; and upon the continent it is artificially combined with sulphuric acid, in order to form alum,§ though we

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* Earthen-ware, according to the Old Testament, was known at an early period to the Jews; and the potter's wheel, there spoken of, was probably the same simple machine as is used at the present day to form round vessels with plain surfaces. The making of porcelain has long been known in China and Japan; but it was accidentally discovered in Europe by a chemist, in the beginning of the 18th century. It was so esteemed by the Romans, that, after the taking of Alexandria, a porcelain vessel was the only part of the spoil retained by Augustus. Dr. Thomson, vol. ii. 286.

† Alumine is of inestimable value for securing the bottoms and sides of canals and reservoirs of water, and composes in a great measure those tenacious earths called *arable* soils.

‡ The beautiful colours which are seen upon porcelain and earthen-ware are given by metallic oxides. Purple is given by gold; red by the oxide of iron; yellow by the oxide of silver; green by copper; blue by cobalt; and violet by manganese.

§ Alum is generally made artificially in France. Chaptal, a chemist of some eminence, has formed a considerable establishment for the manufacture of this very useful article, and has erected immense buildings for preparing sulphuric acid by the combustion of sulphur, totally different from those usually appropriated to such purposes in England. See Annales de Chimie, tome iii.

In England it is not necessary to form alum by art, as the alum-slate is found in great abundance. It is gotten on the sea-coast of the north-east part of Yorkshire, from Whitby to

possess the compound ready formed in its native state.

Why do potters employ a mixture of alumine and silex for earthen-ware?

In making earthen-ware a due proportion of both these earths is necessary; for if alumine*

Stockton, a distance of about 50 miles. The slate, when gotten, is broken to pieces by the aid of fire, and afterwards further acidified, by being frequently moistened, and by exposure to the air. When the efflorescence has taken place, it is put into lixiviating vessels for the extraction of the salt. The saline liquor is then boiled down to the proper strength for crystallization; previous to which is added a portion of alkali, to saturate the superabundant acid, and to favour the crystallization. Indeed, alum cannot be made without a portion of ammonia or potass, as it is a triple salt. All alum is either a sulphate of alumine and potass, or a sulphate of alumine and ammonia. *Urine* is generally used in Scotland, and sulphate of potass in Yorkshire.

I have been informed by one of the most considerable manufacturers of alum, that the account of the English alum-works published in 1678, by Daniel Colwall, Esq. corresponds exactly with the present practice. This paper may be seen in the 12th vol. of the Philosophical Transactions, page 1052.

The first English alum-work was established at Gisborough in Yorkshire, in the reign of Queen Elizabeth, by Sir Thomas Chaloner, who engaged workmen from the Pope's alum-works to superintend it; and kept those workmen till his manufacture was brought to perfection, notwithstanding the bulls and anathemas which His Holiness issued in abundance against him.

One of the most ancient manufactures of alum was at Roche, a city of Syria; whence the name of Roche-alum. See Additional Notes, No. 24.

* For making pottery or earthen-ware, the clay is beaten in water; by which the fine parts are suspended in the fluid, while the coarser sink to the bottom of the vessel. The thick liquid is further purified by passing through hair and lawn sieves of different degrees of fineness; and is afterwards mixed with another liquor of about the same density, consisting of ground flints. This was the composition of the *white stone ware*, about 40 years ago the staple manufacture of the potteries of this kingdom; and it is also that of the finer earthen-wares at present in use, though in different proportions, and with various improvements.

alone were used, the ware could not be sufficiently burnt without shrinking too much, and even cracking; and a great excess of silex would lessen the tenacity, and render the ware brittle.

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introduced by the ingenuity of succeeding manufacturers. This mixture is then dried in a kiln, and, after being beaten to a proper consistence, becomes fit for being formed by the workman into dishes, plates, bowls, &c. The fine white and cream-colour earthen-wares now made in England are fired twice: the first time to give them the requisite hardness; and in that state they are called *biscuit:* they are then dipped in a vitreous composition, and, being subjected to a second burning, acquire a coating of true glass, thence called a glaze. If they are finished with painting in enamel, it is necessary to pass them a third time through the fire. One of the ingredients of this glass (see Note † page 120) being oxide of lead, the workman, whose hands are constantly immersing in the mixture, is subject to *paralysis,* unless due precaution be taken. To prevent it, the manufacturers have of late years assigned to such men a varied employment about their ovens, and furnished them with a dress to wear at the glazing tub, and throw off when they leave it, and a water cistern, soap, and towels near them, *that they may be* more certain, when employed *in the glazing,* to wash their hands before they go to their meals. It is feared, however, that an unhappy opinion of the efficacy of spirituous liquors does more mischief to this class of workmen than any other circumstance; for, attributing to the effect of lead whatever slight disorder occurs, they have recourse, in the first instance, to them as specifics, in such cases, and thus acquire the habit of an immoderate use of what probably affords them a temporary relief, but does not fail to produce a permanent and destructive disease. This is, I believe, the sole opprobrium which falls upon the potter's art; yet even this may be greatly diminished, if not entirely removed, by the precautions above mentioned: however, as it is desirable to preclude the use of lead altogether, the Society for the Promotion of the Arts has offered a premium for a substitute for this glaze, or for a mode of using it which would not subject the men to these dangers.

The *white* and the *brown stone wares* are passed only once through the fire, for at a certain period of the heat they are made to undergo a partial vitrification at the surface, by the fumes of muriate of soda; this salt being thrown into the oven, and the pieces of ware so disposed as to receive the fumes of it on every part of their surface. This method of glazing earthen-

t constitutes the difference between earthen-nd porcelain?

elain is not esteemed good unless it be ompact, quite white, and semi-transpa- ndeed it is chiefly the last quality that con- the principal difference, for earthen-ware ys opaque.

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h salt was introduced into England by two brothers lland, of the name of ELERS, about the year 1700. tled in the neighbourhood of the Staffordshire potteries; remarkable, that the alarm occasioned by the fumes read over the country obliged them to leave it. The ne of these artists was afterwards an active magistrate ounty of Oxford; and *his* son is at present a very re- e English barrister. A similar manufactory was how- n after established at Shelton, in the potteries, by one workmen, named *Astbury*, who had possessed himself secret; and as it became of great utility, it was readily d by the inhabitants, and at length, on the common day ng, (Saturday,) the thick offensive fumes from fifty or nufactories filled the valleys, and covered the hills of a f country extending many miles.

is no doubt that potteries had been established in this Staffordshire, which abounds with *coal*, for many cen- at some depth indeed below the surface strong indica- e been found of the site of *Roman* potteries; but down poch I have been speaking of, the productions and the n of the potters were in much the same rude state as *lot* made his survey of the county.

Messrs. Elers had also the merit of introducing into this a red unglazed porcelain, which they made from a clay the estate they had settled upon in Staffordshire, called *ll*; but it was only the *brown* stone ware, (of the same that now made by the Lambeth potters,) in the compo- which no flint is used, which they glazed in the manner lescribed. The *white* stone ware, and the use of ground pottery, were discoveries of later years, and owe their o the following curious incident:—About the year 1720 (believed to be the *Astbury* above mentioned) travelling lon on horseback, had occasion, at *Dunstable*, to seek a for a disorder in his horse's eyes; and the ostler of the burning a flint stone reduced it to a fine powder, which into them. The potter, observing the beautiful white

*What is zircone?**

ZIRCONE is a peculiar earth, which has been

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colour of the flint after calcination, instantly conceived the uses to which it might be applied in his art; and then introducing into use the white pipe-clays found in the south side of Devonshire, instead of the irony clays of his own country, he readily produced the *white* stone ware. At first the flints were reduced to powder, to the great injury of the persons employed: but the immortal *Brindley*, in the early part of his life, constructed the mills that are at present in use for grinding them in a moist state.

About the year 1750 commenced the inventions and improvements of the late Mr. Wedgwood, who, by combining science with the art, and having the advantage of a highly cultivated taste, not only greatly extended the uses of English pottery, and turned the tables upon the *French* and *Dutch*, who had hitherto exclusively supplied Europe with fine earthen wares, but rendered it an object of admiration, and deserving a rank among the fine arts of the age. This inestimable man has left us an admirable example of what may be effected by cultivated talents and persevering industry. Such investigations as those to which he was accustomed, bring with them their own reward. Such experimentalists

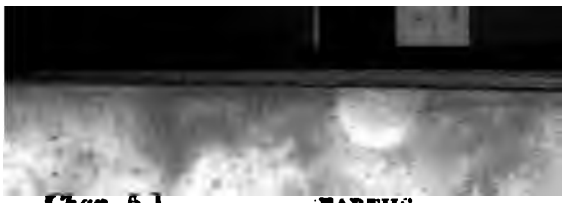
> "Exult in joys to grosser minds unknown,
> A wealth exhaustless, and a world their own."

Porcelain is an artificial compound of great durability. When good, it is of so compact a texture that it would probably endure for ages. There is an octagon tower at Nan-king in China, called the Porcelain Tower, which is entirely covered with the most beautiful china. It is a building of nine stories, nearly 300 feet high, and each story decreases in breadth, as it rises in height. This singular and elegant edifice still retains its original beauty, though it has sustained the continued action of the sun and weather for four hundred years.

An interesting account of the processes which are carried on in the great French manufactory of porcelain at Sevres has been published by Brongniart, who superintends it. See Philosophical Magazine, vol. xiii. and xiv.

The Chinese are said to let their clay remain exposed to the atmosphere at least 20 years before they use it in making porcelain. Some tile-makers in England, who are curious in the article they manufacture, never use their clay till it has lain a year or two in the open air.

* There are reasons for believing that zircone, like the other earths, is a metallic oxide. Sir Humphrey Davy submitted it



soluble compound with sulphuric acid,* and by its tinging flame yellow. Its specific gravity is 4.00.

What are the uses† of barytes?

Barytes forms some of the most useful chemical tests,‡ whether in its pure state dissolved in water, or combined with particular acids: in muriatic acid it is also employed as a medicine. It is capable of making a very tenacious cement, but has not yet been used much in the arts, except by limners as a most excellent water colour.§

What is the origin of strontian?

STRONTIAN was discovered about the year 1787,

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* The most singular property of this earth is the tenacity with which it holds the sulphuric acid when combined with it. It has such an affinity to it, that it will not part with it even to pure alkalies. Hence pure barytes will decompose sulphate of potass or sulphate of soda.

† Barytes has been proposed as a medium for decomposing muriate of soda in a cheap way. The method of using it may be seen in the Annales de Chimie, tome xix. See also a paper of Vauquelin's on this subject in Journal de Phys. 1794, p. 297.

‡ The solution of this earth in water, and in various acids, furnishes excellent tests for chemical analysis. The muriatic acid is often preferred, especially for medical purposes, such as scrofulous and other chronic diseases. Though this earth has been accounted highly poisonous, yet Dr. Johnstone says that he has seen a delicate female take thirty drops of a saturated solution of muriate of barytes *repeatedly* in the course of a day, without even nausea. He therefore concludes that it would require at least 2 or 3 drachms to do mischief.—Essay on Poisons, page 143.

§ Many years ago Mr. Hume discovered the method of making a colour from this earth. It is the only *white* for water painting, that never changes. It has another peculiar advantage, it may be mixed with any other colour without injury. It is sold under the name of "Hume's permanent White."

mine;* infusible by heat; but soluble in the acids, with which it forms soluble sweet-tasted salts,† slightly astringent. This earth is not very plentiful, nor has it yet been employed in the arts.‡

What is the origin of yttria?

YTTRIA is a peculiar earth§ which has been found only in a black mineral from Sweden, called gadolinite; which, besides this earth, contains iron, manganese, lime, and silex.‖

How is yttria to be distinguished?

Yttria, when separated from the mineral, is in

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* Glucine is insoluble in water, and soluble in pure liquid alkalies, in which it further resembles alumine: it also agrees with that earth in being insoluble in pure ammonia, though soluble in carbonate of ammonia.

† From the sweet taste of the salts of glucine, we have reason to believe that Nature, who forms nothing without its use, has endowed this earth with properties which will, some time or other, render it eminently serviceable to the animal economy.

‡ Vauquelin is of opinion, that hereafter this earth will be useful as a mordant in dyeing, and that it may be serviceable in medicine, when it comes to be discovered in greater plenty. Lelievre announced some time ago, that he had discovered the emerald in stones used for repairing the roads near Limoges in Guienne. From this source a large quantity of glucine might be procured.

§ This earth was discovered by Gadolin, a Swedish chemist, in a mineral found at Ytterby, in that kingdom. From this circumstance the fossil has been called Gadolinite, and the earth Yttria.

‖ There is some reason for supposing that yttria may be a metallic oxide. A foreign chemist has lately announced, that when muriate of yttria is heated to redness it gives out oxygenized muriatic acid. I have not heard that any chemist has hitherto succeeded in decomposing this earth.

Sir Humphrey Davy suspects that yttria and glucine are not distinct *primitive* earths, but modifications of other earths.

the form of a fine, insipid, white powder.* It forms sweet and coloured salts with the acids, is insoluble in the caustic alkalies, but easily dissolved in a solution of carbonate of ammonia.†

What is the origin of barytes?

BARYTES was discovered by Scheele in combination with sulphuric acid, in a mineral called ponderous spar, afterwards terra ponderosa.‡ It

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* The specific gravity of yttria is 4.842, which is greater than that of any other earth.

† Though yttria is insoluble in the alkalies, and infusible alone, it may be fused when mixed with borax, and forms a white glass with that salt.

‡ Barytes was discovered by Scheele in 1774. It is always found united either with the sulphuric or the carbonic acid. The best method of procuring this earth pure for chemical purposes, is, to dissolve the carbonate of barytes in very weak nitrous acid, by which means the carbonic acid will be expelled, and then in the usual way, by proper evaporation, crystals of nitrate of barytes will be formed. By exposing this salt to a strong heat, the nitric acid will be dissipated, and pure barytes will be left in the crucible. See Fourcroy and Vauquelin's memoir in the Annales de Chimie, xxi 276. Sulphuric acid is the best test for the presence of this earth.

Bergman gave it the name of *barytes* from the Greek word βαρὺς, *heavy*, this being the most ponderous of all substances except the metals.

Sulphate of barytes is very plentiful in the Derbyshire lead mines; the workmen call it *cauk*. For a description of this mineral, consult Thomson's Chemistry.

A method of crystallizing this earthy salt artificially was pointed out by Withering, in the Philosophical Transactions for 1784.

Casciarole, an Italian shoemaker, discovered that if sulphate of barytes be calcined in a peculiar way it will acquire a phosphorescent quality, and will shine even in water. It is known by the name of Bologna phosphorus. For the method of making it, consult Bouillon La Grange, vol. i. 138; or Nicholson's Chemical Dictionary.

Several of the natural gems and fossils exhibit phosphorescent properties by attrition. In the tremolite this property is so abundant, that the slight friction of a feather is sufficient to excite it.—Murray.

out a great quantity of caloric when sprin-
ith water;* and absorbs carbonic acid when
d to atmospheric air.†

hat state is lime found in nature?

e is never found in its pure state; it is
in a state of combination, generally with
d, and more frequently with the carbonic
as in chalk, marble, limestone, &c.‡ It

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ck-lime has such an affinity to water that it will ab-
-fourth of its weight of that fluid, and yet remain per-
ry. The water becomes solidified and identified with
. The heat therefore that is evolved in the process of
lime, proceeds from the water as it passes to the solid
d not from the earth as is sometimes supposed.

effect of carbonic acid upon lime may be shown by the
g experiment: Add gradually a very small quantity of
mpregnated with carbonic acid, to a jar about one-

is found also in vegetables, and is the basis of

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supposed, to the destruction of marine testaceous animals, which in long process of time formed these extensive and accumulated heaps;

"For in vast shoals beneath the brineless tide,
On earth's firm crust, testaceous tribes reside:
Age after age expands the peopled plain,
The tenants perish, but their cells remain;
Whence coral walls and sparry hills ascend
From pole to pole, and round the line extend.—DARWIN.

Fourcroy, in his Chemical Elements, has given a beautiful account of this process of Nature, to which I refer; as I am persuaded every reader of taste must be charmed with its perusal. See Thomson's edition, part iii. chap. 7, sect. 1.

According to captain Cook, there are in the Southern Ocean perpendicular coralline rocks, formed entirely of sea-shells, which are of such magnitude as to render the navigation of those seas extremely dangerous.

The shells of some testaceous animals in the South Sea are extremely large. The *kemo* shell on the coast of Sumatra is frequently found 3 or 4 feet in diameter, and as white as ivory. See Marsden's History of the Island of Sumatra, page 10.

It may be remarked, that while *testaceous* shells are formed with carbonate of lime, the shells of *crustaceous* animals and the shells of birds' eggs contain also a portion of phosphate of lime. Its use in the former is not known; but the design of Nature in furnishing the shells of eggs with phosphoric acid is very apparent. The body of the egg contains neither phosphoric acid nor lime: it was necessary, therefore, that Nature should provide means of furnishing both these substances, which it does at the expense of the shell, which becomes thinner and thinner during the whole time of incubation, till the living embryon hath appropriated a sufficient quantity for the formation of its bones. Part of the albumen for this purpose combines with the shell, and another portion forms feathers, &c.

One thousand parts of egg-shells are composed of

Carbonate of lime .	896
Phosphate of lime .	57
Gluten and moisture	47
	1000

If fowls are kept in a state of confinement where they can not get at any calcareous earth, they lay their eggs without shells.

animal bones. It occurs likewise in the water of the ocean, and indeed in that of all springs and rivers.*

How is pure lime procured from these minerals?

Carbonate of lime, by whatever name it is called, whether chalk, marble, limestone, oyster-shell, &c. is to be broken into convenient pieces, and piled in alternate layers with coal, furze, or other fuel, in proper kilns, where it is kept for a considerable time in a *white* heat. By this means the carbonic acid and water are driven off, and tolerably pure lime is the product.†

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* This earth is dissolved in such quantities in the waters of Tuscany, that the artists there are said to form *basso relievos* of very considerable hardness, merely by frequently filling their moulds with the waters.

† *Pure* lime should always be kept in well stopped bottles, if for nice experiments; for, without this precaution, it would soon absorb carbonic acid, and become carbonate of lime. If lime-water be exposed to the air, it will soon be covered with a pellicle of carbonate of lime, from the same cause. In like manner, if a little lime-water be put into a glass syphon, and the legs of the syphon be held upwards, so that a person might blow through it without the liquor running out, the breath will be found to give a milky colour to the lime-water, and carbonate of lime will be seen forming at the bottom of the liquor, which will effervesce with acids, and have every chemical quality that it had when in the quarry. This change is owing to the absorption of carbonic acid from the lungs.

Some persons who have occasion for lime of the *best* quality, may be glad to be informed that the earl of Stanhope has established a work, on a new principle, for the express purpose of furnishing this useful article in greater purity than it can be had elsewhere.

Bishop Watson found by experiment, that, upon an average, every ton of limestone produced 11 cwt. 1 qr. 4 lbs. of quicklime, weighed before it was cold; and that when exposed to the air it increased in weight daily at the rate of a hundred weight per ton for the first five or six days after it was drawn from the kiln.

What are the chief uses of lime?

Lime united with the acids is applied to various useful purposes, and, next to silex, forms a material portion of the solid fabric of the terrestrial globe.* In its pure state it is used in many of the arts,† particularly in making mortar for buildings. It is employed by the farmers as a manure; also by bleachers,‡ tanners, sugar-bakers, soap-boilers, iron-masters,§ and others, in their several manufactories, and in medicine.‖

This fact is worth the notice of those farmers who fetch their lime from great distances.

In the Journal de Physique for 1775, page 311, are a plan and description of a kiln for calcining lime *after* it has been reduced to powder, in order that it might be used quite hot without the necessity of its being slaked by water. For some purposes this is found to be very advantageous.

* The inhabitants of towns and houses built on a chalky or limestone foundation are observed to be less liable to infectious or epidemic disorders than those of any other situation.

† Quick-lime well dried and *pulverized* is said (by the French translator of Dr. Henry's Epitome of Chemistry) to increase the explosive effects of gunpowder, when mixed with twice its weight of the latter.

Lime is used in the manufacture of glue. The design of it is to prevent its becoming flexible by the absorption of moisture, and to add to its strength. Some persons use alum for the same purposes.

‡ Quick-lime was used by the ancients for bleaching. Theophrastus, the disciple of Aristotle, and who wrote more than 300 years before Christ, speaks of it in this connexion. He relates an instance of a ship, which was loaded in part with linen and in part with quick-lime, having been set on fire by water that was accidentally thrown over the latter, which fired the linen, and occasioned the destruction of the vessel.

§ The iron ores that are wrought in this country contain a large portion of alumine and silex: in order therefore to flux these earths and more effectually separate the iron, a quantity of lime is usually mixed with the ore in the furnace; lime having the property of rendering the other earths more fusible.

‖ Lime has the property of seizing oxygen from the atmo-

How do you explain the operations of lime in forming mortar and cements?

Pure lime has, when united to a certain portion of water, a very strong affinity for silex, another most essential ingredient in all mortar and cements; for without this it never hardens,—but when mixed in proper proportions, the whole crystallizes, as it gradually imbibes carbonic acid from the atmosphere, and thus in a series of years becomes as hard as unburnt limestone.*

How does lime act so as to be of use as a manure for land?

The use of lime in agriculture may be attributed to the property which it possesses of hastening the dissolution and putrefaction of all animal and vegetable matters,† and of imparting to the soil a power of retaining a quantity of moisture necessary for the nourishment and vi-

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sphere—hence the unhealthiness of rooms newly white-washed. Parkinson.—The design of Nature in giving this property to lime is not as yet apparent.

* When lime is made into mortar, it takes a long time in acquiring the portion of carbonic acid which it possessed in the quarry; but the mortar hardens as this absorption takes place. This accounts for the great strength of some ancient buildings, in which the mortar is found to have a greater degree of firmness than even limestone itself.

The sand which is mixed with lime to form mortar or cement, serves a purpose similar to what is answered by sticks put into a saline solution to favour its crystallization: therefore, the harder and sharper the sand, the better; for, if the matter interposed between the crystals be of a friable nature like chalk, the mortar must be weak. See Additional Notes, No. 20.

† For a further explanation of this chemical process, see Anderson's Essays on Agriculture: he thinks that no quantity of lime can possibly be too great for land.

gorous growth of the plants, corn, &c.:* but there is no good soil that does not contain a certain portion of lime, though always, without exception, combined with carbonic acid.

What is the use of lime in the operation of tanning leather?

Lime is used by the tanner in a state of solution; in this the hides are immersed in order to dissolve the gelatinous part of the skin, and to facilitate the removal of the hair.†

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* Hence lime and chalk are found to be particularly useful on sandy soils. Marle is a mixture of carbonate of lime and clay. See Additional Notes, No. 20. Marles are useful in agriculture only in proportion to the calcareous earth they contain. Unless they contain more than 30 per cent. of lime, they are of no value to the farmer. Of all the modes of trial, the one best suited to the unlearned farmer is, to observe how much *fixed air* the marle gives out; and this he will learn by dissolving a little of it in diluted muriatic acid, and observing what portion of its weight it loses by the escape of this air. Thus, if an ounce loses only 40 grains, he may conclude that the ounce of marle contained only 100 grains of calcareous earth, and that it would be his interest to pay seven times as much for a load of lime as he must pay for a load of marle at the same distance. Dr. Black's Lectures, vol. ii. 120.

Every farmer should ascertain the *nature* of his lime before he uses it in agriculture, as there are many extensive districts in England where the lime is contaminated by magnesia, which renders it injurious to the growth of vegetables. See Mr. Tennant's paper on this subject in the Philosophical Transactions for 1799. The limestone of Breedon in Leicestershire is found to contain half its weight of magnesia. Darwin's Phytologia, page 211.

Magnesian limestone is generally of a fawn colour, but it may be known by its being ten times as long in dissolving in an acid as common limestone. This is the lime which the Yorkshire farmers call *hot* lime.

† The theory of tanning is shortly this: After the impurities

How is lime used in refining sugar?

By boiling the sugar in lime-water the manufacturer deprives it of a certain uncombined acid* which prevents its crystallization.†

What is the use of lime in the manufacture of soap?

Lime is mixed with the alkali in order to deprive it of carbonic acid. The alkali is thus rendered what is called *caustic*, and by this means is fitted to combine with the oil or tallow which is thereby converted into soap.‡

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of the skins are removed, they are steeped in an infusion of oak-bark, which consists of two distinct substances, viz. the gallic acid and the tanning principle. The gallic acid deprives the skins of their oxygen in a gradual manner; and while this is taking place the tan combines with the fibrous part, and forms leather. See Seguin's paper on the improved modes of tanning in Nicholson's Journal, 4to, vol. i. 271; also Sir Humphrey Davy's paper on this subject in the *Philosophical Transactions*, vol. xciii. 233.

* Lime is frequently used by chemists in processes where there is a superabundant and injurious quantity of acid. The lime seizes the acid, and frees the solution from it, by forming with it a neutral salt.

† For the process of refining sugar in England, see Rees's Cyclopædia—article *Sugar*. The account may be relied on, as I know it was written by a gentleman engaged in the business. The method of refining in the French South American colonies is described by Fourcroy, vol. vii. 215.

Dr. Roxburgh has lately published a minute account of the Hindu method of cultivating the cane, and manufacturing the sugar, in the Asiatic Annual Register for 1802.

‡ As different alkalies require different proportions of lime to render them perfectly caustic, every soap-maker should be acquainted with a test by which he may precisely ascertain the necessary quantity.

Having paid great attention to the different processes in this manufacture, I think I am justified in saying that no trade is less understood, even by the people who conduct it, than this.

We have hitherto spoken only of lime and of carbonate of lime:—Is lime found native in any other state of combination?

This earth combined with sulphuric acid occurs in gypsum;* with the fluoric acid in the fluor spar;† with the phosphoric acid in a mineral called *apatite*,‡ and in some precious stones.

What is magnesia?

MAGNESIA is a very soft, white, light earth,§

We have no *English* work on soap-making, and I believe there is nothing in any language worth reading on this subject, except the "Report on the Fabrication of Soaps, made by Darcet, Lelievre, and Pelletier, by Order of the Committee of Public Safety;" in the 19th volume of the Annales de Chimie; but as the French make use of articles which our soap-makers cannot avail themselves of, a great part even of that paper is not applicable to the practice in this country.

* Gypsum is composed of 30 parts of sulphuric acid, 32 earth, and 38 water.—*Kirwan.*

† Lime combined with the fluoric acid forms those beautiful fluor spars which are brought from the mines of Derbyshire. Combined with muriatic acid, large quantities of this earth are held in solution by the waters of the ocean.

‡ The bones of all kinds of animals are formed of this earth and phosphoric acid, in the proportion of about 80 parts earth and 20 parts acid.

The best test for the presence of lime is oxalic acid, which forms with it an insoluble precipitate. Oxalate of ammonia is generally used for this purpose.

§ Sir Humphrey Davy has demonstrated that this, like the other earths, is a metallic oxide. It was with considerable difficulty that he was enabled to separate its base, but he effected it by means of quicksilver and the agency of galvanism. "It sunk rapidly in water, producing magnesia, and quickly changed in air, becoming covered with a white crust, and falling into a fine powder, which proved to be magnesia." The metallic base was named *magnium*, but he now calls it *magnesium*.

produce that endless variety of what, in common language, we call rocks, stones, gems, &c.*

What do you suppose could be the design of Nature in forming so many distinct earths?

The earths have several properties in common;† yet as every earth possesses different and specific properties, it is evident that Nature de-

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attraction, which destroys one compound in order to form another. The paper containing an account of his experiments may be seen in Annales de Chimie, tom. xxxi. Mr. Chenevix's memoir on this subject, in the Phil. Trans. for 1802, is also very interesting.

* Potter's clay is a mixture chiefly of silex and alumine; the colouring earths used as pigments are mixtures either of clay and the oxides of iron, or clay and charcoal; garden mould is a mixture extremely various, sometimes containing silex, alumine, magnesia, iron, lime, and carbon; the common mill-stone is generally composed of alumine and silex; and the crumbling sandstone is a mixture of iron and silex. It is, however, impossible to enumerate the endless diversity of substances which Nature offers ready formed for the use of man; for the mixtures of the earths which are found *naturally* combined comprehend all the varieties of clays, slates, stones, spars, gems, rocks, crystals, zeolites, quartz, flints, &c.

The student may acquire much information on this subject from Weaver's Translation of "Werner's External Characters of Fossils," 8vo.

† A regular classification of the different earths and stones, according to the system of M. Daubenton, may be seen in the first volume of Thomson's Fourcroy.

A few short directions for analysing stones are given in Mr. Parkinson's Chemical Pocket-book, last edition, page 216. There is an excellent paper on this subject in vol. iv. of Dr. Thomson's System of Chemistry, p. 128. Fourcroy's directions are more concise, but they are worth the perusal of those who are not accustomed to this kind of analysis. Further information may be had by consulting the 1st vol. of Kirwan's Mineralogy.

The minerals which are generally the subject of analysis are formed with different proportions of the nine earths and the metallic oxides; such as oxide of iron, copper, nickel, manganese, chrome, &c.

signed them for different and distinct purposes of utility.

You have enumerated the separate uses of most of the earths:—Can you recollect the collective advantages which arise from this class of bodies?

The uses of many of these earths are not yet discovered; but the benefits which we derive from lime, clay, silex, and magnesia are very various and important.

In order to impress your memory, and to finish the consideration of this class of bodies, endeavour to recollect some of the more important uses of those earths with which you are best acquainted?

LIME, then, has an extensive and important use in agriculture;* it is employed in building, &c. and adds much both to the neatness and durability of our dwellings. SILEX is the basis of all mortar and cements, and is a necessary ingredient in earthen-ware, porcelain, and glass. BARYTES is employed in chemical laboratories as a re-agent, and for the formation of salts. MAGNESIA, besides being the basis of several salts, is of great use in medicine; and ALUMINE, by a due mixture with silex, is capable of forming vessels for chemists

* "The goodness of a soil depends upon its being able to retain the quantity of moisture which is proper for the nourishment of vegetables, and no more. Now the retentive power of a soil increases with the proportion of its alumine, lime, or magnesia; and diminishes as the proportion of its silex increases." The Essay on Soils, by Dr. Alderson of Hull, is, perhaps, the best paper that has yet appeared on this subject.

as powerful caustics* when applied to the animals.†

many alkalies are there?

e are three alkalies;‡ two of which have alled *fixed* alkalies, the other the *volatile*

h are the fixed alkalies?

fixed alkalies are potass§ and soda.‖

have they been called fixed¶ *alkalies?*

use they will endure a great heat and still unchanged.

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eems that causticity depends on chemical affinity, and caustic substance corrodes the matter to which it is ap- consequence of its tendency to *unite* with that matter; it continues to act upon it until it has saturated itself

What substances enter into the composition of these alkalies?

Till lately the fixed alkalies were considered to be *simple* substances, chemists not having been able to decompose them; but they are now found to be *compound* bodies.*

Have we any historical account of the discovery of these substances?

Potass was known to the ancient Gauls and Germans;† and soda was familiar to the Greeks and Hebrews. This latter substance was known to these ancients by the name of nitrum.‡

I have retained it in this work. These alkalies have surely some claim to the title of *fixed*, for they require a red heat to dissipate them; whereas the other alkali becomes volatile at a very low temperature.

* It will be recollected, that, in the *first* edition of the "Chemical Catechism," written seven years ago, I offered this opinion of the compound nature of the alkalies. The late galvanic experiments of Sir Humphrey Davy have confirmed the truth of this conjecture, and proved beyond all doubt that potass and soda are both metallic oxides. See Experiments, No. 248 to 255, and Additional Notes, No. 67.

At the great explosion of the iron furnace at Colebrook Dale by the bursting of the dam of the river, on the 7th of September, 1801, its whole contents were thrown into the air, and it is said nothing was found afterwards but potass, soda, and prussiate of potass.

It has been ascertained by experiment, that potass is formed in what are termed nitre-beds, or collections of the materials from which nitre is procured, though it could have pre-existed in none of them. How this takes place we certainly at present are quite ignorant.

† These people were probably the *inventors* of soap, as we are told by Pliny, that they made soap with the ashes of vegetables and tallow. A soap-boiler's shop with soap in it was discovered in the city of Pompeii, overwhelmed by Vesuvius, A. D. 79. See "*Miss Starke's Letters from Italy.*"

‡ This substance is found native in Egypt, and is there called

What is the origin of potass?

Potass is chiefly procured by lixiviation from the ashes of burnt wood, and other vegetable substances;* but as it exists in minerals and earths,† there is reason to believe that plants receive it from the earth during vegetation;‡ hence it may be proper to discard the word *vegetable* entirely, when speaking of this substance.§

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natron; a name not much unlike that which it bore among the Jews and Greeks.

* A table of the quantities of alkali procured from different kinds of wood, may be seen in a valuable memoir on the fabrication of potash in Annales de Chimie, tome xix. 157. Directions, by Vauquelin, for burning vegetables in a proper manner for this purpose, will be found in the same volume, page 194.

Potash is prepared in large quantities in wine countries, by the incineration of wine-lees and must. This article is known in France by the name of *cendres gravelées*.

Potass has been discovered in the *pumice stone*; in the zeolite; and in the leucite, an earth of *the siliceous kind*. It has also been found in the *aluminous ores* of La Tolfa; but never in an *uncombined* state that I know of, except in the water of some wells.

† It has been said, that potass cannot be procured from vegetables without burning them *previously* to their being lixiviated, or treating them with nitrous acid, or by some process capable of furnishing oxygen and nitrogen; and, indeed, it has been found, that if vegetables be soaked for some time in water and then burnt, they will afford no potass.

‡ Potass was called the vegetable alkali, because it was supposed to exist only in vegetables, though it is now found in some minerals. Soda was called mineral alkali, because it exists in mineral salts.

§ Soda, as distinguished from potass, has been known but of late years. Even half a century ago, the salt which was artificially produced by the mixture of muriatic acid and potash, was called "*re-generated marine salt*;" which shows that chemists had not then learnt to distinguish between potass and soda. Some of the properties of soda were known in times of remote antiquity. A Hebrew writer speaks of washing with natron. Jeremiah ii. 22.

What is the origin of soda?

Soda is generally procured from the ashes of *marine* plants;* but its great depository is the ocean, soda being the base of sea-salt;† or muriate of soda.

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* The *salsola soda*, which grows among the cliffs on the sea-coast, is endowed with the property of decomposing sea-salt. By some process of vegetation, it separates the muriatic acid and absorbs the soda. Hence it acquired the name of *saltwort*. This plant is collected by the Spaniards with great care, and burnt for the manufacture of BARILLA, which is a considerable article of commerce. Thus nature has providently furnished the inhabitant of the otherwise barren coast with a source of employment, and has enabled him to supply the interior with an article of indispensible necessity, for ages before the science of chemistry could afford him other means of decomposing muriate of soda.

"The *saltwort's* starry stalks are thickly sown,
Like humble worth, unheeded and unknown."

CHARLOTTE SMITH.

Most of the peasantry in the Shetland Isles and in the Highlands of Scotland are supported by collecting sea-weeds, and burning them into KELP, an article which produces great revenues to the lairds of those districts. Many of the wretched inhabitants of those dreary regions have nothing to depend upon for subsistence, but a miserable pittance, which they acquire in this employment.

"The kind impartial care
Of Nature nought disdains; thoughtful to feed
Her lowest sons."

The best account of the manufacture of kelp will, I believe, be found in "Jameson's Mineralogy of the Scottish Isles." See also Repertory of Arts, vol. xii.

Soda, combined with carbonic acid, is found mixed with earth in Hungary, Bohemia, and Switzerland; also in China, Syria, Persia, and India.

† Soda is procured also by chemical process from sea-salt, which is found in immense masses under the earth's surface in many countries, particularly in Poland, Hungary, Spain, and England.

An interesting memoir on the decomposition of this salt, published by order of the Committee of Public Safety, may be

How is it that marine plants give out soda, while those which grow in the interior of the country afford potass?

This can only be accounted for by supposing that vegetables have the power, during vegetation, of decomposing sea-salt, and retaining the soda in their constitution.

Is soda found in any other state?

Soda is likewise found in great plenty combined with carbonic acid in the natron beds of Egypt,* and in the East Indies ;† it occurs also in various

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seen in the Annales de Chimie, tome xix. 58. It occupies 98 pages, and contains a detailed account of several effective processes. It may perhaps be the means of saving some individuals from loss and disappointment, if I inform them, that I have myself repeated most of those processes in a reverberatory furnace, built for that particular purpose, capable of producing an intense heat, and sufficiently capacious to allow some hundred weights of the materials to be operated upon at once; and that I am of opinion that none of the means there directed can be profitably employed in this country during the present high price of salt. The decomposition by potass, or by the oxides of lead, presents the fewest difficulties; but even these methods cannot be lucrative, unless at a time when potass and lead are at moderate prices.

* The natron lakes of Egypt annually produce a large quantity of mineral alkali. It probably arises from the decomposition of muriate of soda, by means of carbonate of lime assisted by the heat of the climate. In summer the water of these lakes is evaporated by the sun, which leaves a bed of natron generally two feet thick; and this is broken up by wedges, and packed for the European markets.

Berthollet formed an *artificial* natron bed in one of the gardens of the National Institute, by the mixture of carbonate of lime, silex, and muriate of soda. After a time, a partial decomposition was effected, which was evident from the incrustation on the surface changing the colour of test paper.

† Natron in large quantities is frequently sold at the English East India Company's public sales, and is brought by their vessels from China and other parts of the East.

other parts of the world, though never in a state of purity.*

What are the distinguishing properties of these two alkalies?

The fixed alkalies are very similar in their general properties;† but are easily distinguished

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* Soda exists native in borax, and in muriate of soda, which is our common culinary salt. Near Cordova in Spain there is said to be a mountain of this salt 500 feet high, and nearly three miles in circumference. The mine of Cracow in Poland is computed to hold salt enough to suffice the whole world for many thousands of years.

I copy the following extract from a letter received by a friend of mine from the Rev. Dr. Allison, dated Borden-Town, N. Jersey, Dec. 3, 1803:—"There has lately been discovered on the Missouri in Louisiana, a mountain of pure rock salt of the best quality, 80 miles long, 45 wide, and of an immense height. The surface is barely covered with earth, and there is not a tree or shrub growing on it. This is established as a fact, and some of the salt has been sent to Marietta on its way to Washington city. Various caves of saltpetre are found in its vicinity."

Soda has also been found in the proportion of 4 per cent. in common whinstone, and in volcanic lava. Edinburgh Trans. vol. v. As these specimens contained lime and muriatic acid, it is very probable that the soda was produced by the decomposition of muriate of soda by the agency of fire.

The *chrysolite* of Greenland, which is an insoluble fluate of alumine, is found to contain 36 per cent. of soda.—Klaproth.

Soda is one of the substances found in the bile of animals. Whenever this alkali occurs native, it is always in a *mild* state; and as it cannot combine with oils to form soap, unless it be *caustic*, this causticity is given it for these manufactories by artificial means. It is worthy of remark, that Nature has furnished the bile with soda in a state of *causticity*, which gives it the property of combining with and saponifying the fat or oily substances taken into the stomach, and rendering them soluble in the other animal fluids. What account can be given of this deviation from the usual course of nature, but the important purpose which it serves in the animal economy?

† When the fixed alkalies are in a state of purity, it is impossible by inspection to distinguish them from each other; and yet they form, by union with the *same* acid, salts very opposite in their saline properties and appearance. Thus the sul-

by the variety of salts which they form with the acids; and by potass being more deliquescent than soda.

Is there any chemical test by which you can distinguish these two alkalies?

There are many; but a solution of the ore of platina in nitro-muriatic acid will answer this purpose most completely.*

What are the chief uses of these alkalies?

The fixed alkalies have various uses in surgery and medicine;† they are the bases of several

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phuric acid and soda form a salt very soluble in water, which crystallizes in long separate six-sided prisms, effloresces in the air, and undergoes a watery fusion by the action of heat; whereas, the same acid and potass form a salt extremely difficult of solution, which crystallizes in hexahedral pyramids, or in short prisms, crossing each other at right angles, is not affected by the action of the air, and decrepitates in the fire.

The oxalic acid has been used as a test to distinguish the mineral from the vegetable alkali. With the latter it forms a very soluble salt, but, with the former, one of difficult solubility.

The acetous acid is one that may be employed, as it forms a *crystallizable* salt with soda, and a *deliquescent* salt with potass. Potass may also be known from soda by supersaturating it with tartaric acid, with which it forms a salt very *insoluble* in water.

The alkalies, when combined with carbonic acid, form very *soluble* salts, while the earthy carbonates are nearly *insoluble* in water.

* If a little of any alkaline solution be poured into a solution of the ore of platina in nitro-muriatic acid, a yellow precipitate will be seen, if the alkaline solution contains potass; but if it contains only soda, no precipitate will occur. The peculiar advantage of this test consists in its ready application; whereas the old tests required time to ascertain the nature of the salts formed by their means.

† Fourcroy is of opinion that soda is more proper for medicinal purposes than potass, on account of its analogy with animal substances, which *always* contain it; while on the contrary no portion of potass is found in them.

salts; are employed much in the arts;* and are of great importance to the analytical chemists.†

How are the fixed alkalies employed in the arts?

The fixed alkalies are used in large quantities by the glass-maker,‡ the dyer, the soap-maker, the colour-maker, and by various other manufacturers.

In a former chapter we noticed the use of fixed alkali in making glass:—What is the use of it to the dyer?

The alkalies are known to have the property of altering the hue of most colours;§ they are therefore employed with this view by the persons who are engaged in this trade.

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* The greatest consumption of the fixed alkalies in this country is the manufacture of soap. They are also largely employed in bleaching, and in the manufacture of glass. Soda and potash are also both used in washing, and for other domestic purposes; as they powerfully unite with all greasy substances, which they render soluble in water.

† See note ‡ page 160.

‡ Soda has the property of fusing silex with more facility than potass; hence it is preferred by those glass-makers who have made trial of both these alkalies.

Soda is preferred to potash in most of the manufactures, because it is much less acrid, and does not attack or weaken the texture of linen goods, nor corrode and destroy utensils of wood, metal, &c. as potash does.

It is curious to observe that the alkalies combine with *transparent* olive oil, and produce *opaque* soap; and that they unite with *opaque* sand to form *transparent* glass. How various are the properties that have been impressed upon those primary materials of the universe, that were intrusted to man for the promotion of his convenience and comfort!

§ The fixed alkalies are also employed to facilitate the extraction of the colouring matter from a few of the foreign woods, and in some processes to precipitate the colours from metallic salts.

Why are the alkalies employed in making soap?

An alkali is an essential ingredient in soap, as it is the only article capable of converting tallow or oil into a saponaceous substance, and enabling it to combine with water.*

Why are the fixed alkalies employed in making colours?

Many colours are now manufactured in this country which cannot be made without an alkali: thus, animal matters are always incinerated with

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* To make soap, it is necessary to employ a fixed alkali in a caustic state. In this country the business is usually conducted in the following manner: Spanish barilla or Scotch kelp is broken in pieces, or coarsely ground by a horse mill; and, when mixed with a sufficient quantity of quick-lime to absorb the carbonic acid, the whole is thrown into large wooden or iron vats, and covered with water. In large works, these vats are generally of cast iron, and sufficiently capacious to hold 3 or 4 tons of alkaline ashes. At a proper time, the water, impregnated with the caustic alkali, is let off into iron receivers below, and the vats are covered again with water, which after standing a sufficient time, is let off as before. This liquor is called soap-boilers' ley. When a sufficient quantity of this is prepared, Russian or English tallow is put into a large iron boiler, and melted with a portion of the above-mentioned alkaline ley. At first the tallow appears liquid like oil, but during its boiling it acquires by degrees consistence as it saponifies. When the alkali is uniformly combined with the tallow, the weak liquor is pumped from beneath the soap, and fresh leys are added in their stead. These are boiled as before, till the soap exhibits certain appearances well known to the manufacturer: it is then cooled down, and poured into deep wooden frames 15 inches wide and 45 inches long; where it remains till it has acquired a sufficient degree of solidity to be cut up for sale. It is the *alkali* which gives soap its detergent quality, and which renders it soluble in water. The tallow serves to moderate the sharpness of the alkali, and to prevent its injuring the hands of those who use it.

In making yellow soap, resin is used in the proportion of about 1 part to 3 or 4 parts of tallow. The resin makes the soap more detersive, and enables the manufacturer to sell it

an alkali to form Prussian blue; a fixed alkali is also employed as a flux in the formation of the potters' blue from cobalt; and what are called French and mineral greens are made by precipitating copper from its solutions by means of these alkalies.

What are the other uses of these alkalies?

They are employed in making alum;* in bleaching linen;† in scouring wool; and in many other processes too various to be enumerated.

From whence is this country supplied with these alkalies?

The greatest part of the potass used in this country comes from America and Russia; but the *kelp* of our own coasts, and the *barilla* of Spain‡

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cheaper. Common fish oil, when its price permits, is also used in yellow soap.

Potass is the alkali used for soft soap, which is a distinct and separate trade in this country. A solution of this alkali in a caustic state is boiled with fish oil; and when the oil is sufficiently saponified, and a complete union of the materials formed, the *ichole* is poured into small casks for sale; the water having combined with the oil as well as the alkali.

* Alum, which is a triple compound, cannot be perfect without the addition of a portion of potass or ammonia. For this purpose the British manufacturers generally use kelp, (which contains a quantity of potass as well as soda,) or black ash, which is an article made from the waste leys of the soap-boilers, and which, with other salts, generally contains a portion of muriate and sulphate of potass. Putrid urine is sometimes used, on account of the ammonia which it affords. For the process of alum-making, see page 122.

† The design of using alkali in bleaching, is to loosen and carry off that particular substance in the cloth which occasions its brown colour, and which Dr. Home says is a kind of heavy oil. For further information consult Pajot des Charmes on Bleaching.

‡ The soda of Spain is procured from the *salsola*, as has been noticed, and also from the *basis maritima*. The Sicily barilla which is imported into this country, is chiefly made by the inci-

and of the islands of Teneriffe and Sicily, furnish us with most of our mineral alkali.*

Are these alkalies sold in a state of purity?

No: both potash and soda always contain

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neration of the *zostera maritima*. These plants must be endowed with some very peculiar organization for the decomposition of sea-salt, superior to that of other marine vegetables; or why does not sea wrack (the *Fucus* of Linnæus) of the British shores, and other sea plants that are burnt for kelp, yield a proportionate quantity of soda? Whenever I have had occasion to lixiviate ordinary kelp, especially Irish kelp, I have not failed to observe that the neutral salts which precipitate from the solution, are not muriate of soda, as might have been expected, but *muriate of potass*. And this salt is so abundant, that I have often had many hundred weights of it from a single ton of kelp. From this circumstance I am induced to believe that marine plants (excepting those that are cultivated for barilla) yield *potass* by incineration, and not *soda*, as has generally been imagined; and that the soda which occurs in kelp is produced by the operation of the potass on the sea-salt in the vegetable, or on that which is thrown into the mass by the burners to increase its weight: for a solution of carbonate of potass, poured into a *boiling* solution of sea-salt, always produces an immediate decomposition, the result of which is carbonate of soda and muriate of potass.

* As we are indebted to foreign countries for most of our fixed alkalies, it would be a great national benefit if some ingenious chemist could discover an expeditious as well as economical mode of recovering the alkalies after they have been used for manufacturing or domestic purposes. The waste liquor might be evaporated; and if the residuum were calcined, the potass or soda would be recovered entire, and endowed with all the valuable properties which it originally possessed; as it is by nature indestructible. The desideratum is, how to divest it of its impurities, and regenerate it at a small expense.

By examining "The Report of the Committee of the House of Commons appointed to inquire into the Laws relating to the Salt Duties," I find that from the 5th of Jan. 1800 to the 5th of Jan. 1801, the following quantities of alkali were imported into Great Britain:

	Cwt.	*Declared Value.*
Barilla	172,454	£.362,153 18 6
Pearlash	44,401	128,765 2 6
Potash	135,401	284,342 3 6

carbonic acid* and water; and are often contaminated with earths, sulphur,† and other impurities.

Have alkalies any peculiar affinity for sulphur?

Both potass and soda, as well as ammonia, have a strong affinity for sulphur; they combine by trituration or heat, and form *sulphuret* of alkali,‡ formerly called *hepar sulphuris*, or "liver of sulphur."

What is the nature of sulphuret of alkali?

Its colour is similar to that of the liver of animals; its taste is acrid and bitter; and it has the property of decomposing water.§

How are the alkalies of commerce purified for the use of the chemist or manufacturer?

Potass or soda is generally mixed with a portion of quick-lime to divest it of carbonic acid,

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* The potash and soda of commerce contain nearly one 5th of their weight of carbonic acid, beside lime, silex, and other impurities.

† An ash which contains 20 per cent. of pure alkali is capable of taking up 15 parts of sulphur. Such ashes may be desulphurated by three processes: by calcining them in an open furnace exposed to a rapid blast of air; by saturating them with any vegetable acid; or by exposing them in a situation to imbibe carbonic acid. See a paper on this subject in the Irish Phil. Transactions for 1789.

‡ If equal parts of sulphur and pure potash be triturated together in a mortar, the sulphur will soon acquire a green colour, the temperature of the mixture will be raised, and a *sulphuret of potass* formed. Carbonate of potass or soda will answer for this purpose as well as the pure alkalies, if heat be employed.

§ Sulphuret of potass or soda is similar in colour to the liver of animals; it cannot exist but in a *dry* state, for it decomposes water when dissolved, and then sulphuretted hydrogen is produced.

hen lixiviated in proper vessels to obtain a
n of the caustic alkali, free from other im-
s. When it is required *perfectly* pure for
urposes, the alkali is dissolved in alcohol,
rified by a peculiar process.*

the fixed alkalies ever used in a state of com-
n with carbonic acid?

bonic acid gives potass and soda the pro-
of crystallizing readily:† it also renders
mild,‡ and fit for purposes in which caus-
kali would be improper;§ hence carbonate

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e different methods which have been followed *to purify* d alkalies, are detailed at length by Mr. John Thomson Notes on Fourcroy, vol. i. 373. Another method has roposed by Lowitz, which may be seen in Nicholson's

of potass is employed in medicine, and carbonate of soda for washing and other domestic uses.

What is the chemical name of volatile *alkali?*

It is called ammonia.

What are the properties of ammonia?

Ammonia is urinous and caustic: but it does not corrode animal substances like potass or soda. Its most simple state is that of gas.* In some of its combinations it is so extremely volatile, that it will bear no degree of heat without being dissipated.†

As this alkali is a gaseous substance, how has it ever been applied in the arts?

Ammonia has an affinity for water,‡ with which it readily combines, and forms *liquid* ammonia; in which state it is generally used.§

What is the composition of ammonia?

Ammonia is a compound of hydrogen and ni-

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means of double affinity. But when these re-agents are employed to precipitate either of the three latter substances, if too much be used the precipitate will be *re-dissolved*: some nicety therefore is requisite in separating magnesia, manganese, and iron, from their solutions by this means.

* Ammoniacal gas is lighter than atmospheric air, in the proportion of 3 to 5; and, like it, is elastic and invisible; but it causes the death of animals that are obliged to breathe it.

† Ammonia has another peculiar property, that of reducing the oxides of metals to a metallic state. Ammonia being composed of hydrogen and nitrogen, the hydrogen seizes the oxygen from the metal and forms water, while the nitrogen escapes in a gaseous form. Some metals are oxidized and dissolved by liquid ammonia.

‡ Water is incapable of dissolving either hydrogen or nitrogen, and yet when these are united in ammonia their nature is so changed that they become very soluble in water.

§ It is owing to the levity of ammonia, that water becomes specifically lighter in proportion to the quantity of gas it con-

trogen, in the proportion of about two parts of the former, and eight of the latter.*

Is this alkali capable of being decomposed?

Yes: ammonia may be decomposed by the electric spark. Oxygen gas will also decompose it by the assistance of heat, and then nitrous acid and water will be the result.† If passed over red-hot charcoal, it will combine with part of the charcoal and form *prussic acid*.

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tains. Next to hydrogen, ammonia is the lightest of all the gaseous bodies. Its specific gravity compared with hydrogen is as 8 to 1. One hundred cubical inches of it weigh about 18 grains.

* One thousand parts of ammonia consist of 807 parts of nitrogen, and 193 parts of hydrogen. This is the result of experiment; but Sir Humphrey Davy has lately, by means of galvanism, separated a peculiar substance of a metallic nature from ammonia. See Add. Notes, No. 67.

By the following process ammonia may be formed, so as to become evident to the senses in a short time. Take some filings of tin or zinc, pour on them some moderately dilute nitrous acid. After a short time stir into the mixture some quick-lime, or caustic alkali, and a very strong pungent smell of ammonia will be produced. For the rationale of this experiment consult Higgins on Ammonia, and a curious paper by Dr. Milner in the Philosophical Trans. vol. lxxix. 300.

† Dr. Priestley was the first chemist who decomposed ammoniacal gas; indeed he was the first who procured it in a state of purity; but I believe Berthollet was the first who proved its composition by synthesis as well as analysis.

The decomposition of ammonia may be shown by the following experiment: Fill four-fifths of a long glass tube with strong oxygenized muriatic acid, and the remaining fifth with water strongly impregnated with ammonia, and invert it in a saucer of water. When the tube is inverted, the ammonia, on account of its lightness, will pass through the oxygenized muriatic acid: but by its passing a strong effervescence is produced, and a decomposition ensues. When the effervescence has ceased, a portion of nitrogen gas will be found in the tube.

In this experiment the oxygen of the oxygenized muriatic acid combines with the hydrogen of the ammonia, and forms water; while the other component part of the ammonia, nitrogen, becomes disengaged in the form of gas. When the oxyge-

What is the effect of galvanism on ammonia?

A very different result may be obtained if ammonia be decomposed in contact with mercury, by means of galvanism; for in this case a metallic substance of a very uncommon nature may be separated from this alkali.*

How is ammonia procured?

All animal and vegetable substances, when in a state of putrefaction,† will furnish ammonia: this alkali is, however, generally procured in England by a dry distillation of bones, horns, and other animal substances.‡

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nized muriatic acid is thus reduced to common muriatic acid, it unites with another part of the ammonia, and forms with it muriate of ammonia. But if the idea which has lately been suggested by Sir Humphrey Davy, that oxymuriatic acid is a simple undecomposable substance, should be confirmed, then we should say that it is the hydrogen of the ammonia uniting with the oxymuriatic acid that in this experiment converts it to common muriatic acid.

* This is one of the last, and certainly not the least surprising of Sir Humphrey Davy's very important discoveries; for, as he himself observes, "the more the properties of this amalgam obtained from ammonia are considered, the more extraordinary do they appear." Mercury, by combination with about one twelve thousandth part of its weight of new matter, is rendered a solid, and at the same time so expanded in volume that its specific gravity is reduced from 13.5 to less than 3; while all its metallic characters of colour, lustre, opacity, and conducting powers, remain unimpaired.

† As the quantity of ammonia obtained from different substances corresponds with the quantity of nitrogen which they contain, and knowing that ammonia is one of the products of putrefaction, it has occurred to me that a manufacture of volatile alkali might be established with advantage on any part of the coast where herrings, pilchards, &c. arrive in such shoals as to be employed in manure for land. Besides, as fish bones contain more phosphoric acid than those of quadrupeds, the bones might be advantageously employed afterwards in the manufacture of phosphorus, &c.

‡ Ammonia is also found in mineral waters. According to

What are the uses of ammonia?

In a liquid state ammonia has various uses in our manufactories,* and in medicine; it is a valuable re-agent to the chemist; and when combined with carbonic acid it takes a concrete form and a beautiful white colour, being then the article known in commerce by the name of *volatile salts*.†

Dr. Austin, ammonia is formed whenever iron rusts in water which has a free communication with the air. Phil. Trans. vol. lxxviii. 379.

For chemical experiments ammoniacal gas may be procured thus:—Mix one part of powdered sal-ammoniac with two parts of powdered quick-lime in a retort, and apply the heat of a lamp, which will disengage the gas in abundance. On account of its affinity for water, this gas must be received over mercury.

Ammoniacal gas may be procured also by heating strong liquid ammonia, and collecting the gas as before.

Muriatic or acetic acid are the usual tests employed to discover the presence of ammonia. If either of these be held over any thing evolving ammonia, white fumes will appear, which are owing to the ammonia uniting with the acid, and forming a visible cloud, which is a true neutral salt in vapour.

* Ammonia is of use in making archil, an article in great demand with dyers. A Florentine merchant about the year 1300, having accidentally observed that urine, which contains ammonia, imparted a very fine colour to a certain species of moss, he made experiments, and learned to prepare archil. Berthollet.

It is said that this alkali will give to *new* brandy all the qualities of that of the oldest date. The method consists in pouring five or six drops of aqua-ammonia into each bottle of brandy, and shaking it well, that it may combine with the acid, on which the taste and other qualities of the new liquor depend. Bib. Phys. Econ.

† When ammoniacal gas is passed into carbonic acid gas, the two gases become condensed, and a crystallization of carbonate of ammonia, in silky fibres or fine powder, takes place upon the internal surface of the vessel. This is a beautiful experiment; but it must be made over mercury, and not upon water, as water would absorb the ammoniacal gas.

Are there any other uses to which ammonia is applied?*

Ammonia is serviceable in dyeing, and in staining ivory; but its principal use is in making the muriate of ammonia, of which it is the basis.

How is ammonia formed into muriate of ammonia?

Muriate of ammonia is formed by combining ammonia with muriatic acid. It is known in commerce by the name of *sal-ammoniac*.†

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* It has lately been discovered that ammonia is useful in vegetation. See Dr. Darwin's Treatise on Agriculture and Gardening.

Muriate of ammonia has been found native in the neighbourhood of volcanoes, in some of the mountains of Tartary and Thibet, and in the waters of some lakes in Tuscany.

† In this country liquid carbonate of ammonia is saturated with sulphuric acid, which forms sulphate of ammonia. This is decomposed by muriate of soda, from which result muriate of ammonia and sulphate of soda. The former is sublimed into cakes, and the latter crystallized for Glauber's salt.

In France a very considerable manufactory of sal-ammoniac was established a few years ago, on a plan very different from the usual practice. Leblanc de Franciade was the author of the process. He covered the brick floor of an oven heated to redness, with common salt, and poured thereon sulphuric acid. The muriatic acid gas which arose was conducted by a brick gutter into a large leaden chamber, where it met with a stream of ammoniacal gas, conducted thither from animal matters burning at the same time in three iron cylinders, placed in a furnace beside the former. These gases condensed by mixture, which was hastened by an eolipile heated by the same furnace. A full account of the process may be seen in Annales de Chimie, tom. xix. 61: it will, however, be better understood by examining a drawing of the apparatus in one of the volumes of the Journal de Physique; but not having at present access to that work, I cannot point out the volume in which it may be seen.

Sal-ammoniac is very profitably formed in France also by the distillation of animal substances, and mixing the aqueous product with the mother-waters of the saline springs of Ka

Muriate of ammonia being formed by two gaseous substances, how does it acquire solidity?

It may appear surprising that the union of two gases should produce a hard ponderous body; but this may be attributed to their loss of caloric. The bases of these gases having a greater affinity for each other than they have for caloric, they combine intimately whenever they come in contact; and the compound having less occasion for caloric than the separate ingredients, the caloric is given out, and a solid is produced.*

What are the uses of sal-ammoniac?

Sal-ammoniac is also employed in many of our manufactories, particularly by dyers, to give a brightness to certain colours;† also by bra-

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Meurthe, Mount Blanc, &c. which contain muriate of lime and muriate of magnesia. By this mixture a double decomposition takes place; and the carbonate of lime and magnesia, being insoluble, precipitate, while the muriate of ammonia remains dissolved. The latter solution is then evaporated to dryness, and the salt sublimed for sale. See Annales de Chimie, tom. xx. 186.

* This mixture may be considered one of the most striking chemical combinations with which we are acquainted. Ammoniacal gas, and muriatic acid gas, are two of the most pungent and volatile substances known; they are so volatile and gaseous, that when in a state of purity neither of them can be condensed; and yet these gases are no sooner thrown together than they form a solid and inodorous substance, void of volatility, and of little taste.

† Sal-ammoniac is used also by dyers in what they call composition, to prevent the tin from precipitating. In tinning metals it is of use to cleanse the surfaces, and to prevent them from oxidizing by the heat which is given to them in the operation. This salt is employed also in the assay of metals, to discover the presence of iron.

ziers, tinplate-workers, and others; and in medicine.

From whence was sal-ammoniac procured before it was made in this country?

Sal-ammoniac was formerly brought from Egypt sufficient for the supply of all Europe;* but it is now made in various parts of Great Britain, particularly in Scotland, where it is formed by a peculiar process from soot.

Is ammonia capable of entering into any other combination?

Yes: ammonia is capable of forming salts with most if not all of the acids.†

Can you recapitulate the origin of the different alkalies?

Yes: the volatile alkali is procured from bones and other animal matters; potass, or vegetable alkali, from the ashes of weeds and burnt wood; and soda, or mineral alkali, from the ashes of some

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* Sal ammoniac acquired its name from the Temple of Jupiter Ammon, it being first made in the neighbourhood of that temple. According to Pliny, there were large inns in the vicinity of this famous temple, where the pilgrims, who came to worship, lodged; and who usually travelled on camels. The proprietors of these stables had some contrivance for preserving and concentrating the urine of these beasts, and the salts which it produced were afterwards sublimed in glass vessels for sale. Pliny, lib. xxxi. c. 7.

† If ammoniacal gas be brought in contact with either of the acid gases, both lose their aeriform appearance, and a solid salt is produced. These salts are called *ammoniacal* salts. For an account of their properties consult the chapter on Salts.

marine plants, also from sea-salt or muriate of soda.*

What is the natural inference from a consideration of the nature and production of the alkalies?

The reflection which naturally arises from a consideration of this subject, is, that the pristine organization of matter, whereby the effete recrementitious parts of animals and vegetables are made capable of producing useful and powerful substances, evinces, that infinite Power and Wisdom, conjoined with consummate Beneficence,

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* Soda may be readily procured from muriate of soda, common salt, by methods alluded to, page 151. As the act of parliament which imposes the tax upon salt, allows it to be used duty free for the separation of mineral alkali, to be consumed in making glass, a manufacture of soda has within these few years been established for that purpose at Wormbridge *near* Wellington, in the county of Salop. I understand that at this place considerable quantities of martial pyrites are found intermixed with coal, and that the sulphuric acid obtained from this mineral is used in the decomposition. I have found by operations in the large way, that if muriate of soda can be converted by any means to a *sulphate*, carbonaceous matter alone, at a red heat, will finish the decomposition.

Near the town of Wednesbury in Staffordshire, and Dudley in Worcestershire, there are masses of coal on fire, which have been burning for ages, owing probably to the decomposition of pyrites. In some cases, where the sulphurous vapour meets with aluminous earth, alum is formed upon the surface. An account of these subterranean fires may be seen in Plot's History of Staffordshire. We read also of a combustible ground of this kind, near Baku in Persia, where the followers of Zoroaster perform their devotions. The carburetted hydrogen gas that arises from this ground is so abundant, that the priests have conducted it by hollow canes into one of their temples, where it burns continually, and is looked upon to be "the sacred flame of universal fire."

can effect the most *important* changes, by the most *unlikely* agents; and can convert to valuable purposes, substances which to us appear totally useless and inert.*

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* The following is not an inapt illustration of this economy of Nature.

"Organic forms with chemic changes strive,
Live but to die, and die but to revive;
Immortal matter braves the transient storm,
Mounts from the wreck, unchanging but in form."

CHAPTER VII.

OF ACIDS.

*WHAT is an acid?**

Most of the acids are substances which produce that sensation on the tongue which we call *sour*;† but some substances are classed with the acids which have not this characteristic—though they possess some of the other properties of acids.

What are the properties of acids?

Acids‡ change the blue, green, and purple

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* The acids differ from each other in their appearance and properties as much as any class of bodies we are acquainted with; it is therefore difficult to give a definition of an acid. In general they are liquids, but some of them take a solid, and others a gaseous form; some are mild, others corrosive; some are pungent and volatile, others are mixed and inodorous.

† According to Fourcroy, the stronger the attraction of oxygen for the acidifiable radical, the weaker is the taste of the acid: this shows that the corrosive quality of the stronger acids is owing to the *easy* separation of this principle, and its more or less rapid transmission to animal substances.

‡ It is desirable as soon as possible to give the chemical student correct ideas of the properties of the acids and alkalies. To this end let him be early instructed in the use of chemical tests. If he be accustomed to carry a few test papers in his pocket-book, it will be a very rational amusement to try the succulent vegetables which he will meet with in his walks, many of which will be found to contain acids of different kinds. The hope of making an important discovery will furnish an additional zest to this employment. Litmus paper is a good test for acids; and the same paper when reddened by vinegar, and afterwards dried, is a proper test for alkalies. Should litmus not be at hand, common writing-paper rubbed over with the rind of the radish will answer every purpose.

juices of vegetables to red;* and combine with alkalies,† earths, or metallic oxides,‡ so as to form those compounds called *salts.*

What is the origin of acids?

Most of the acids owe their origin to the combination of certain substances with oxygen,§ which has been called the acidifying principle.

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* This is so general, that we know of only one exception. Indigo may be dissolved in concentrated sulphuric acid, and yet its original blue colour will be preserved.

† All those substances which can saturate the alkalies, and cause their properties to disappear, ought to be classed among acids.

‡ From some late galvanic experiments of Sir Humphrey Davy, it appears that acids combine with alkalies and metallic oxides in consequence of their being in opposite states of electricity,—that is, that acids are naturally negative, and metals and alkalies positive,—and that hence an union would take place between them, independently of any other power than electricity. He has also demonstrated, that, if an acid be put in a state of positive electricity, it refuses to combine with an alkali, and that, when an alkali is made negative, it refuses to combine with acids, as may be seen in the Philosophical Transactions for 1807, page 1. A brief abstract of the experiments will be found in the Additional Notes to this volume, No. 58. However, since the publication of this paper, Sir Humphrey Davy has said that "he does not suppose that chemical changes are OCCASIONED BY electrical changes, but that these are *distinct* phenomena, produced by the *same power*, acting in one case on masses, in the other case on particles." Davy's Chemical Philosophy, vol. i. page 165.

§ The substances which are combined with oxygen to form acids are (in all the decomposable acids) *combustible* substances. Indeed, several of the acids are the *product* of combustion: witness the sulphuric, the phosphoric, &c. Four of the metals, and all the other simple combustibles, except hydrogen, are convertible into acids. All bodies, to which the properties of an acid have been ascribed, are either combustibles, supporters of combustion, or may be produced by the process of combustion.

It is proper to remark that some of the acids are the productions of art, and are not known to exist in nature. This is the case with the mucous, the suberic, &c

How is it known that oxygen imparts acidity?

This is built upon analogy; for it is found that most of the acids contain oxygen, and that they lose their acidity exactly in proportion to the quantity of oxygen which is taken from them.*

Are there any other means of ascertaining this?

Yes: some acids may be decomposed, and deprived of their oxygen, and others may be formed by a direct combination of oxygen with certain radicals.†

Do the same radicals always combine with an equal portion of oxygen?

No: some of these acidifiable radicals com-

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* Many of the acids may be decomposed and deprived of their oxygen, by combustible bodies. Any combustible body, that has a greater affinity for oxygen than oxygen has for the radical of the acid, will decompose that acid. Charcoal, when made red hot, will in this way decompose sulphuric acid.

† This is shown by the composition of sulphuric acid, which, for experiment, may be formed thus: Mix a little sulphur coarsely powdered with one eighth of its weight of ground nitre. Put the mixture upon a small tile, and place the tile upon a low stand in the middle of a large flat glass or earthen dish. Then pour a small quantity of water into the dish, and procure a large glass jar to invert over the brimstone, so as that its edges shall dip into the water, which must be deep enough to form a water lute. Things being thus prepared, the brimstone is to be set on fire in several places, by means of a red-hot iron, and immediately covered with the jar. The sulphur will burn with great rapidity, and will be chiefly converted into sulphuric acid, which may be concentrated by evaporating the superfluous water. In this process the sulphur unites with the oxygen of the atmospheric air within the jar, at the same time that the heat and light, which are unnecessary in the new compound, are evolved, and become sensible to our feelings: the result is a new substance widely different from either, viz. sulphuric acid. The use of the water is to absorb the gas, and render it liquid.

bine with different proportions of oxygen, and consequently produce different states of acidity.*

How do chemists distinguish this difference?

When two acids have the same radical, but contain different quantities of oxygen, they are distinguished by their termination.† The name of that which contains most oxygen ends in ic, the other in ous. Thus we say *sulphuric* acid, and *sulphurous* acid: *phosphoric* acid, and *phosphorous* acid.

Have acids ever any other degree of acidity?

Attempts have been frequently made to supersaturate several of the acids with oxygen, but in only one instance with success.

Which of the acids has been thus supersaturated with oxygen?

The muriatic acid,‡ forming with two different

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* The first portion of oxygen converts some bodies into oxides: the second, into that class of acids of which the specific names drawn from their particular bases terminate in *ous*, as the sulphurous acid; the third degree of oxygenizement changes some of these into that division of acids which are distinguished by the termination in *ic*, as the sulphuric acid; and lastly, we can express a fourth degree of oxygenizement by adding the word *oxygenized* to the name of the acid, as oxygenized muriatic acid.

† The term OXYGEN is derived from the Greek words οξυς γενομαι, signifying *that which produces or generates acids*: but as Sir Humphrey Davy has discovered that this substance is necessary also to the production of the alkalies, some other term, surely, should be found that would be more applicable to this wonderful invisible agent! Had the framers of the new nomenclature happened to have called it *hydrogen*, no objection, that I can perceive, could have been made to it.

I have not thought it advisable to make any alteration in

s of oxygen, two other distinct acids, called
ized muriatic acid,* and hyperoxygenized
ic acid.†

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mineral, the vegetable, and the animal
ms, all furnish bases or radicals, which be-
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greater number of the acids are evidently
ed to oxygen for their acidity, but there

are substances that possess acid properties which contain no oxygen.* Until lately, there were also three acids whose composition was unknown.†

How are the acids classed by chemists?

The acids were formerly divided into three classes, viz. the mineral, the vegetable, and the animal acids; but the more useful and scientific way of dividing the acids is into two classes only.

How are the acids now divided?‡

The undecomposable acids, and those which are formed with two principles, are comprised in the first class; while those acids which are formed with more than two principles compose the second class.§

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* Sulphuretted hydrogen has all the properties of an acid without oxygen. And it has not yet been proved that prussic acid contains any oxygen.

† Those acids were the muriatic, the fluoric, and the boracic: these, however, have lately yielded to the power of voltaic electricity, and their bases have been separated.

‡ Those acids of the first class, which are formed with two principles only, are composed of oxygen and some other substance which is called their radical. The acids of the second class are composed chiefly of oxygen, hydrogen, and carbon; though some of them contain a portion of nitrogen, as mentioned in a former note.

§ Fourcroy, in his last work, entitled "Philosophie Chimique," divides the acids into four classes: 1st, those with known radicals; 2d, unknown ditto; 3d, single ditto; 4th, compound ditto: but I conceive that the above division is better calculated for an elementary treatise.

In the first class we have also the hyperoxygenized muriatic acid; but as this acid has never been exhibited in a separate state, its properties are very little known. In the second class we have also the mellitic acid; but as this acid has been found only in a very rare mineral, its properties are likewise very little understood.

strong acid taste. It has a great attraction for water,* and, when combined with the alkalies, the earths, or the metallic oxides, forms with them those salts called *sulphates*.†

What is the SULPHUROUS *acid?*

The sulphurous acid, like the sulphuric, is a combination of sulphur and oxygen, but with less oxygen, or, we may say, with more sulphur, than the latter.‡

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* Sulphuric acid and water combine so intimately that the compound gives out a large portion of caloric. Four pounds of this acid mixed with one pound of water will raise the thermometer to 300° of Fahrenheit.

The sulphuric acid of commerce is never perfectly pure,—it always contains a portion of sulphate of lead and sulphate of potass. The former comes from a partial dissolution of the lead of the chamber in which it is made, and the latter from the nitre which is always used in the process.

Concentrated sulphuric acid does not act upon lead unless by the assistance of heat. It acts slowly upon iron; but if diluted it dissolves iron with great rapidity. Excepting iron and zinc, most of the metals are insoluble in diluted sulphuric acid.

† Sulphuric acid is a test for barytes: a single drop poured into any solution of this earth instantly causes a white precipitate. It is also a good test for lead. I know, however, of *one* case where this acid cannot detect the presence of barytes, and that is when sulphuric acid is contaminated with this earth. Mr. Hume has shown, that sulphate of barytes is completely soluble in sulphuric acid. Phil. Mag. vol. xiv. 357.

‡ Sulphurous acid gas is produced by the *slow* combustion of sulphur. Its specific gravity compared with hydrogen is as 30 to 1. 100 cubical inches of it weigh about 68 grains. If this gas be received in water, the gas combines with it, and sulphurous acid will be the result. Water at 40° absorbs one third of its weight of sulphurous acid gas, and acquires a specific gravity of about 1.0513.

Sulphurous acid gas may be procured by the following process: Put into a glass retort two parts of sulphuric acid and one of mercury, and apply the heat of a lamp; the mixture effervesces, and a gas issues from the beak of the retort, which may be received in glass jars filled with mercury and standing

What are the properties of sulphurous acid?

Sulphurous acid in the gaseous state is invisible like air, but of a strong suffocating smell.* It is readily absorbed by water, and then forms liquid sulphurous acid. It is capable of uniting with various bases, and forms the salts called *sulphites.*

What is the MURIATIC *acid?*

The muriatic is a peculiar acid obtained from

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in a mercurial trough. In this process the mercury in the retort combines with part of the oxygen of the sulphuric acid; and the sulphuric acid, having lost a certain portion of its oxygen; is converted into *sulphurous* acid.

Any combustible substance will decompose sulphuric acid; by combining with a portion of its oxygen, and sulphurous acid gas will be evolved.

* This gas is very abundant in the environs of volcanoes. It was the vapour of sulphurous acid which suffocated Pliny the naturalist, in that eruption of Vesuvius by which Herculaneum was swallowed up, in the year of Christ 79. Anxious to observe the effects of the eruption, he staid in the house of a friend too long, and paid for his temerity with his life.

Sulphurous acid gas, according to Sir Humphrey Davy, p. 274 of his Elements of Chemical Philosophy, is composed of nearly equal parts by weight of sulphur and oxygen. The liquid acid is administered in asthmas.

Sulphurous acid gas is used by manufacturers in bleaching silk. A slow combustion of sulphur is promoted in a close chamber, and the goods are exposed to the gas as it is produced. Thus, silks which are dyed by archil of a dark lilac are brought to a beautiful flesh-colour by the fumes of this gas. Flesh-coloured silk stockings are coloured in this way.

Sulphurous acid possesses very slight acid properties. Instead of changing vegetable blues to a red, as acids generally do, it invariably renders them white. Thus, if a red rose be held in the fumes of a brimstone match, the colour will soon begin to change, and at length the flower will have become white. By the same process, fruit-stains or iron-moulds may be removed from linen or cotton cloths, if the spots be previously moistened with water.

sea-salt.* Until lately, the radical or base of this acid was entirely unknown.†

What method is made use of to collect and preserve the muriatic acid?

Muriatic acid is distilled from sea-salt by means of sulphuric acid, and collected in appropriate receivers, where it is condensed in water, for which it has a powerful affinity.‡

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* Glauber was the first who procured muriatic acid from sea-salt by means of sulphuric acid; ground tiles, clay, or alum, having till then been used as the medium of distillation. It is also remarkable that this able chemist employed a series of receivers for this process, similar to those now in use; and adapted them to each other *exactly* in the manner directed by Mr. Woulfe. This inestimable apparatus, therefore, which Woulfe has given to the public as his own, was drawn and described by John Rudolph Glauber more than 100 years before his time. See plate 1. to the Treatise on Philosophical Furnaces.

Muriatic acid was known only in a liquid state till Dr. Priestley taught us how to procure it perfectly pure in a gaseous form.

† The decomposition of this acid was a desideratum with the first chemists of Europe for many years. Berthollet imagined that it was a compound of nitrogen, hydrogen, and oxygen, and Dr. Lambe supposed that its base was sulphuretted hydrogen; but nothing satisfactory was said upon the subject till Sir H. Davy favoured us with the result of his experiments. According to this illustrious philosopher, muriatic acid is a compound of hydrogen and oxymuriatic acid. The facts from whence he drew this conclusion are fully detailed in the Philosophical Transactions for 1810.

‡ Muriatic acid is disengaged from muriate of soda in the state of gas, by a process similar to that for drawing the nitric acid. It preserves its gaseous state even in the coldest temperature, unless it come in contact with water; and if thrown upon ice it melts it in an instant. It is nearly double the specific gravity of atmospheric air.

Liquid muriatic acid, or water saturated with this gas, is about the spec. grav. 1.196. The muriatic acid of commerce varies from about 1.120 to about 1.164.

Bergman says, that 100 parts of muriate of soda contain 52 of muriatic acid and 6 of water. That this statement is erroneous,

What are the properties of muriatic acid?

This acid in the gaseous* state is invisible like air; and has a pungent suffocating smell.† With water it forms the liquid muriatic acid, which preserves the smell of the gas, and gives out white fumes when exposed to the atmosphere. This acid is much employed in the arts,‡ and in chemical laboratories. With various bases it forms the salts called *muriates*.§

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any one may satisfy himself by experiment. I have frequently tried it in the large way, and could never procure more than 44 parts of acid and water from 100 parts of dried muriate of soda. In forming muriatic acid, every gallon of water employed, absorbs, according to Murray, 360 gallons of muriatic acid gas. This accounts for the great heat which is evolved during the operation.

* Muriatic acid gas may be obtained for chemical experiments, by pouring one part of sulphuric acid upon two parts of dry muriate of soda in a tubulated retort, and collecting the gas, as it becomes disengaged, over mercury in a pneumatic apparatus. This gas may also be collected by heating the muriatic acid of commerce in a glass retort.

Retorts are not always of glass; they are sometimes made of stone-ware, or iron. They are of various sizes, from eight ounces to eight or nine gallons. The best stone-ware retorts are made by Messrs. Wedgwoods. Glass ones may be had at the large glass-warehouses in London, and elsewhere. A great variety of all kinds for experiments are sold by Messrs. Knights, in Foster-lane, Cheapside.

† Sulphuric phosphoric, nitric, and other acids may be decomposed by charcoal; muriatic acid is unalterable by any of the combustibles with which we are acquainted.

Muriatic acid will decompose the carbonates, the phosphates, and most other salts; but it is itself generally expelled in its turn by the sulphuric acid.

‡ Muriatic acid is the best test for silver. If a single drop be poured into any solution containing this metal, a copious precipitate will immediately follow, owing to the affinity of this acid for silver, and the insolubility of muriate of silver.

§ Sir H. Davy supposes that, in all cases where muriatic acid is employed to dissolve the metals, hydrogen is separated from the acid so as to convert it to the oxymuriatic acid, or chlorine;

What is the OXYMURIATIC *acid?*

According to Sir Humphrey Davy, the oxymuriatic acid is a simple substance.* It is known in the gaseous state, and in combination with water: in the latter form it is commonly used in the arts.

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and that the products are not muriates, but real oxymuriates of such metals as may have been dissolved.

Muriatic acid attacks oxide of iron with more rapidity than the sulphuric. It dissolves tin and lead. At a boiling heat it oxidizes copper.

Muriatic acid removes the stains of common ink, but it does not affect printers'-ink. It is therefore recommended for cleaning old books and prints. Half an ounce of red lead being added to three ounces of common muriatic acid, will render it fit for this use. Where writings have been effaced for fraudulent purposes with this acid, sulphuret of ammonia and prussiate of potash will revive the writing, and discover the artifice. Very old writing may be revived in this way. If indigo and oxide of manganese be added to common ink, it will prevent its being effaced by oxymuriatic acid.

The citric acid is proper for removing ink stains from linen, but they are best removed when recent. If they remain long on the cloth, the iron of the ink acquires that degree of oxidizement which renders it insoluble in acids. When ink stains are thus become what are called *iron-moulds*, they may be removed by oxalic acid, or by first washing them with a solution of sulphuret of potash to absorb the oxygen, and then applying the acid of lemon as usual.

* Oxymuriatic acid, or chlorine, is a peculiar gaseous body which was discovered by Scheele in 1774: it is procured by the mixture of oxygen gas with common muriatic acid; and it was always supposed to be a compound of muriatic acid and oxygen. But if it be true, as Sir Humphrey Davy asserts, that common muriatic acid is a compound of oxymuriatic acid and hydrogen, and that these are both simple undecomposable substances, a different explanation must be given of the operation of the manganese in producing oxymuriatic acid; and we can account for its production in no other way, than by supposing that the oxygen gas decomposes the muriatic acid, and absorbs its hydrogen, and that both these gases unite in the proper proportions to produce water.

If oxymuriatic acid be exposed to light, it will soon be converted to common muriatic acid. See Note, article Light.

Oxymuriatic acid gas may be obtained for chemical experi-

What are the properties of oxymuriatic acid?

The oxymuriatic acid gas is so suffocating, that it cannot be breathed without great injury;* yet it will support combustion. This acid discharges vegetable colours;† it burns all the me-

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ments by the following method: put into a retort a little black oxide of manganese in powder; and pour upon this double its weight of strong muriatic acid; connect the retort with the pneumatic trough, and receive the gas over water. When the ascension of the gas slackens, apply the heat of a lamp, and it will be disengaged in abundance. Its specific gravity is to that of hydrogen, nearly as 33.5 to 1.

If a small quantity of liquid oxymuriatic acid be wanted for experiment, it may readily be formed by dissolving a few grains of oxymuriate of potass, and adding the solution to an ounce of common muriatic acid. It is of a yellowish green colour, which was the cause of its being called *chlorine*, a name given to it by Sir Humphrey Davy.

The variolous poison will not take effect when mixed with oxymuriatic acid. Hence Fourcroy imagines that this acid would prevent the effects of hydrophobia. See his paper on oxygen in *Annales de Chimie*.

Accounts have been received from Spain, that in the midst of the dreadful contagion which reigned in that country, the inhabitants of those houses where fumigations of oxymuriatic acid were used, had no attacks of the sickness, and enjoyed the best health.

* The death of the ingenious and indefatigable Pelletier was occasioned by his inhaling by accident a large portion of this gas. A consumption was the consequence, which in a short time proved fatal.

† Acids in general change blue vegetable colours to red; but this makes them white. Instead of considering it as one of the acids, it would be more proper, as Sir Humphrey Davy has remarked, to call it an acidifying principle. It has not been decomposed either by electricity or galvanism; which is a presumptive proof of its being a simple substance.

The great use of oxymuriatic acid is in bleaching. The manufacturer might derive considerable advantage from the perusal of Mr. Rupp's paper, on the use of this acid, in the fifth volume of the Memoirs of the Manchester Society. See also Charnes on Bleaching, 8vo, Robinsons, 1795. C. Potel of the Academy of Dijon has shown that the fears of those who suppose this

tals,* and is the only acid that will dissolve gold and platina.† With various bases it forms salts, called hyperoxymuriates.*

What is NITRIC *acid?*

Nitric acid is one of the constituent parts of nitre or salt-petre.§ It is a composition of oxygen and nitrogen,‖ in the proportion of about

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process *burns* the cloth are groundless; and that, if the operation be performed by a careful workman, it improves the texture of the cloth instead of injuring it. Phil. Mag. vol. xiv.

* Metals beaten into thin leaves, or reduced to powder, inflame when thrown into a vessel filled with this gas, provided the temperature be not lower than about 70°, and present a kind of shower of fire. The following is a pleasing and instructive example:

Prepare a jar of chlorine (oxymuriatic gas,) and suspend in it a piece of Dutch metal, or copper-foil; it will immediately inflame, and the combustion will continue till the whole is consumed, affording a very striking spectacle. It will however soon subside in the jar, and form a substance exactly similar to the native muriate of copper brought from Peru. In this experiment the evolution of heat and light is no absolute proof of oxidizement; for this may be attributed to the intensity of the action of the acid and the metal on each other.

† Nitro-muriatic acid, it is true, will dissolve gold; but this may be owing to the muriatic acid having been converted to oxymuriatic acid.

Mr. Humboldt has found that seeds which do not commonly germinate in our climates, or in our hot houses, and which of course we cannot raise for our gardens, or hope to naturalize in our fields, become capable of germinating when immersed for some days in a weak oxymuriatic acid. This interesting discovery has been turned to advantage in some botanic gardens.

‡ For an account of these salts see page 220, &c.

◊ Nitric acid was known to Raymond Lully in the thirteenth century; but it was Mr. Cavendish who discovered its component parts, in the year 1785. See his paper in the Philosophical Transactions for that year.

‖ If a proper mixture of these gases be made in a glass tube, and a number of electric explosions passed through the mixture, the gases will unite, and *nitric acid* will be the product. As nitric acid is formed of the same substances with atmospheric

30 parts by weight of the latter, to about 70 of the former.*

How is nitric acid obtained?

Nitric acid is obtained by distilling two parts of nitre and one part of sulphuric acid in a glass retort, and collecting the gas in proper receivers.† This acid, which at first contains nitrous gas, is in a great measure deprived of it, and rendered transparent and colourless by the application of heat in a subsequent process.

What are the properties of nitric acid?

Nitric acid is clear and colourless, like water; its smell is pungent, its taste exceedingly acid,

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air, we have no difficulty in accounting for the natural production of salt-petre.

* These proportions refer to nitric acid in the state of gas, and were ascertained by Sir Humphrey Davy, who has now stated the specific gravity of this gas, when compared with hydrogen, to be about 28 to 1; and that 100 cubical inches of it weigh 65 grains. Elem. of Chem. Phil. page 282.

It is curious that the gases which compose atmospheric air, so necessary to our existence, should, in different proportions, produce also one of the most corrosive acids.

22 parts of oxygen, mixed with 78 —— of nitrogen, } form atmospheric air.
—— 100

70 parts of oxygen, with 30 —— of nitrogen, } form nitrous acid, or aquafortis.
—— 100

Surely none but Deity could have conceived the production of such *different* substances from the *same* principles!

† The manufactories of this acid are commonly called AQUA-FORTIS WORKS. The acid is drawn of different strengths, according to the purposes for which it is designed. It is used in dyeing, in refining gold, in medicine, and in a great variety of manufactories. For more on this subject, see Additional Notes. No. 65

and its action on animal substances very corrosive. It has the property of permanently staining the skin yellow. It has a great affinity for water;* is capable of oxidizing most of the metals,† and with various bases forms the salts called *nitrates.*

What constitutes the acid of commerce, called NITROUS *acid?*

Nitrous acid is nothing more than nitric acid‡ impregnated with variable portions of nitrous gas.§

What are the properties of nitrous acid?

Nitrous acid is very similar to *nitric* acid in its

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* It appears very singular that nitrate of barytes, which is so soluble in water, is perfectly *insoluble* in nitric acid. This was first noticed by Mr. Hume. See his observations on barytes, in the 14th volume of the Philosophical Magazine.

† If nitric acid be poured on iron filings, the acid will in part be decomposed; its oxygen will render the metal soluble, and the nitrous gas will be thrown out in copious red fumes.

‡ It was formerly supposed that this acid differs from *nitric* acid in this,—that it contains less oxygen: hence it was called, agreeably to the new nomenclature, *nitrous* acid; but it is now found that this is not the case: it is merely nitric acid coloured by nitrous gas, or nitric oxide. For a further account of this gas, see chap. xi.

§ Dr. Priestley having separated nitrous gas from nitric acid, by means of iron, he received the gas under an inverted vessel filled with water, and found it a transparent *colourless* gas, resembling air; whence it appears that it is red or coloured, only when combined with atmospheric air. To Dr. Priestley we owe the discovery, that nitrous gas is converted into nitrous acid by its union with oxygen and water. See Priestley on Air.

On the principle that oxygen gas is necessary to convert nitrous gas to nitrous acid, Dr. Priestley invented his eudiometer, to discover the degree of purity of atmospheric air.

properties;* but its colour varies according to the proportions of nitrous gas which it has absorbed, and the water that it contains.†

What is CARBONIC *acid?*

Carbonic acid‡ is a combination of carbon and oxygen. It was formerly called fixed air, on account of its being so intimately combined in chalk, lime-stone,§ magnesia, &c.

What are the properties of carbonic acid?

Carbonic acid is invisible when in the state of gas, and unfit for combustion,‖ or respiration.¶ Water by pressure, may be made to absorb

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* Nitrous acid is generally used for purposes of manufacture and experiment. The *nitric* acid is principally employed in medicine. Two parts of either nitrous or nitric acid, and one of muriatic acid, form aqua regia, or nitro-muriatic acid, the true solvent of gold. It is curious that aqua regia has less specific gravity than either of the acids from which it is composed.

† The changes which take place on the addition of water to strong nitrous acid exhibit very curious phænomena. Different portions change its colour to a blue, a green, a yellow, &c. while the vapours which rise from it preserve their original flame-coloured red.

‡ It is to Dr. Black we owe the discovery of carbonic acid gas. Mr. Keir was the first who suspected it to be an acid; and Dr. Priestley afterwards announced that this gas entered into the composition of atmospheric air.

§ Carbonic acid is composed of 18 parts carbon and 82 oxygen; which has been ascertained by analysis as well as synthesis. Mr. Tennant was the first who decomposed this acid. This he effected by the following means: He burnt phosphorus in a close vessel, in which was a portion of carbonate of soda. The phosphorus absorbed the oxygen from the carbonic acid, and the carbon was separated in the form of a black powder.

‖ If this gas be poured from a wide-mouthed jar upon a lighted candle, it will be as effectually extinguished as by water. Its superior gravity to atmospheric air, and its unfitness for supporting combustion, may also be shown by pouring a common glass full of this gas into another tall glass containing a short taper burning within it.

¶ Fourcroy says, this gas, largely diluted with atmospheric

three times its bulk of this gas; by which it acquires an agreeable acidulous taste.* Carbonic acid enters into combination with the alkalies, with earths, and metallic oxides; and forms with them those salts called *carbonates*.

What is PHOSPHORIC *acid?*

Phosphoric acid is a compound of oxygen and a peculiar substance called phosphorus.‡

How is phosphoric acid procured?

Formerly phosphoric acid was procured only by burning phosphorus in oxygen gas; but, since it is known that this acid is a component part of animal bones,§ we now procure it at a much cheaper rate.

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air may be inhaled without danger, by patients who have symptoms of ulceration, or inflammation of the lungs; and that it will either cure these complaints or retard their destructive effects. If so, common soda water might be serviceable to such persons.

* Carbonic acid gas is found in abundance in many natural waters. Those of Pyrmont, Spa, and Seltzer, are instances; the last, particularly, is highly impregnated with this acid. These waters are so pleasant and salutary, that various imitations of them, made in this country, are sold under the names of single and double soda water. They are manufactured by several houses in London, equal in every respect to the natural waters imported from the continent.

† The earthy carbonates are insoluble in water. Hence, breathing into a phial of lime-water renders it turbid. Owing to this, lime-water is a good test for the presence of carbonic acid.

‡ During a great part of the last century, phosphoric acid was supposed to be a modification of the muriatic acid. This error originated with Stahl. In 1743 Margraff distinguished it from all other acids, and in 1772 Scheele discovered that it was a component part of animal bones.

§ When animal bones are divested of their oil and jelly, the earth which remains is chiefly lime united with phosphoric acid. It is worthy of notice, that phosphate of lime is found

What are the properties of phosphoric acid?

Phosphoric acid, deprived of water, is solid and transparent;* when liquid, it has a thick oily appearance, if not too much diluted; it is of considerable gravity, and has a very acid taste.† It

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in abundance also in milk. This seems to indicate, as Fourcroy beautifully remarks, "that Nature thought fit to place in the first nourishment of animals a quantity of osseous matter, with a view to the necessary celerity of the formation and growth of the bones in the earliest stage of their lives." This fact is probably unknown to some who study natural history, and is one of the numerous instances of the beneficence of the Creator, exemplified by the science of chemistry. The more we know of the minutiæ of matter, and of the laws by which it is governed, the greater occasion shall we have to admire the excellence of contrivance and the benevolence of intention of the Omnipotent Artificer. Let the advocates for chance consider the aforesaid fact, and say, if they can, that phosphate of lime is found in animal milk, in consequence of *fitting*, and that it occurs by *accident* where it performs so important an office in the animal economy.

It is a remarkable fact, that the nearer the female approaches to the period of parturition the more is the milk charged with this calcareous phosphate; and that it is not till the digestive organs of the infant are sufficiently strengthened to answer the purposes and the work of animalization, that this earthy salt disappears from the milk of the mother. See Nicholson's Journal, 4to, vol. i. 205.

* Pure phosphoric acid obtained, without the addition of water, by burning phosphorus in oxygen gas, has the form of white, snowy, light flocks, of a very strong acid taste. By exposure to the air it attracts humidity, and becomes a *fluid* acid. Forty ounces of phosphorus will produce more than 100 ounces of dry acid.

† Phosphoric acid may be concentrated till it is of greater specific gravity than sulphuric acid; but though the taste is very acrid, it does not possess a causticity sufficient to burn organic substances, like the latter, whose oxygen is retained with less obstinacy.

If phosphoric acid be exposed to heat, it gradually becomes thick and glutinous; and if the heat be continued it acquires more consistence, and at last melts into a solid transparent glass. This phosphoric glass must be preserved from the action of the

forms by its union with earthy, alkaline, and metallic bases, that variety of salts which we call *phosphates.*

What is the PHOSPHOROUS *acid?*

This acid contains a smaller proportion of oxygen than the phosphoric acid. It is procured by the *slow* combustion of phosphorus;* for when phosphorus is heated it burns *rapidly*, and the product is phosphoric acid.

What are the properties of phosphorous acid?

Phosphorous acid is a dense, viscid liquid, with an acid taste, and emits the smell of garlic when heated. This, like the phosphoric acid, may be decomposed by charcoal, but cannot be obtained in a concrete state. It has not yet been applied to any use. The salts formed with it are called *phosphites.*

What is FLUORIC *acid?*

The fluoric is an acid of a very peculiar na-

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atmosphere, or it will be gradually dissolved again into liquid phosphoric acid. If the phosphoric acid has been fused in an *earthen* crucible, it will not be deliquescent nor soluble in water.

This acid has been prescribed by some physicians as an antiseptic, cooling, and solvent medicine, and as an external application in osseous tumours.

* Phosphorous acid is generally prepared by exposing sticks of phosphorus to the action of atmospheric air, in a glass funnel, and receiving the acid, as it forms, in a bottle placed underneath. Two or three pieces of broken glass placed in the neck of the funnel to support the phosphorus, and a small quantity of distilled water put into the receiving bottle, complete this simple apparatus. The pieces of phosphorus should be placed so as not to touch each other. Phosphorous acid consists of 20 phosphorus and 15 oxygen; and phosphuric acid of 20 phosphorus and 30 oxygen.

ture,* found in the fluor spar.† This mineral is a natural production, composed of fluoric acid and lime.

What are the properties‡ of fluoric acid?

In the state of gas it is invisible, like air. Water rapidly absorbs it, and forms liquid fluoric acid.§ It has an acid taste, and the peculiar property of corroding silex.‖ Though it has been

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* Fluoric acid is obtained by pouring sulphuric acid upon the powdered spar in a leaden retort, and applying a gentle heat. The sulphuric acid expels the fluoric, and unites with the lime in its stead. This acid has been discovered also in the enamel of the human teeth, and in ivory. Vauquelin has found it likewise in the topaz.

Fluor spar requires its own weight of concentrated sulphuric acid to disengage the fluoric acid gas, which must be condensed in water to form liquid fluoric acid. To preserve the liquid acid, it should be kept in vessels of lead or platina.

† Fluor spar is found in many parts of Europe, particularly in Derbyshire. It is employed in the manufacture of ornamental vases, &c.

‡ This acid has somewhat of the smell of muriatic acid, but is much more corrosive. According to Mr. Murray, it exceeds all other acids in its saturating power, in as much as it neutralizes a larger quantity of any base. It acts so powerfully on silex, that it is impossible to use glass vessels for its distillation. A glass retort would be destroyed before a pound of the gas could be obtained. It combines with the siliceous earth of the glass, and carries it over with it in distillation.

Its action on glass may be shown by strewing some powdered fluor spar on the surface of a pane of glass, and pouring a little sulphuric acid upon it. The sulphuric acid will disengage the fluoric acid from the spar, which will act upon the glass immediately as it becomes disengaged.

§ There are two combinations of this acid, which are very interesting. The one is called *silicated fluoric gas*; the other the *fluoboric gas*. For the methods of preparing them see Sir Humphrey Davy's Chem. Phil. part i. page 366, &c.

‖ If a small animal or reptile be exposed to the vapour of this acid, drawn in glass, the animal moisture will absorb the acid,

decomposed, the nature of its radical is not yet known.

What is the use of fluoric acid?

Fluoric acid has not been used except for etching upon glass.* It appears that it was first employed for this purpose in the seventeenth century.†

What is BORACIC *acid?*

The boracic is a peculiar acid separated from a

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and the silex will be precipitated, so as to give it the appearance of a real petrifaction, or an animal covered with stone.

* It has been a fashionable employment for young ladies to etch landscapes and other drawings on glass by means of this acid. They cover the surface of the glass with wax, and trace any kind of drawing upon it by cutting out the wax with proper instruments. The piece is then put into a leaden receiver, and the gas, disengaged from the fluor spar by means of an Argand's lamp, is thrown in upon it. In this way drawings of great beauty are made, as imperishable as the glass *itself*. A complete apparatus may be had of Messrs. Knights, Foster-lane, for about four guineas: it is so contrived, that a lady may operate with it in a sitting-room with great safety; and by varying the process, the full effect of light and shade may be given to the drawings: for, if *liquid* fluoric acid be used, the lines will be transparent; whereas, if it be applied in the state of *gas*, they will appear dark and opaque. Great caution, however, should be observed in the employment of the liquid fluoric acid, as it quickly destroys the skin and produces tedious wounds.

The frontispiece to the third edition of this work, I have reason to believe, exhibits a more favourable specimen of printing from glass etched by fluoric acid, than any that has hitherto been produced. In France, barometers, thermometers, and other glass instruments, are graduated by means of this acid. It might be usefully employed for engraving labels on glass bottles designed to hold the corrosive acids.

† Henry Swanhard, an artist of Nuremberg, having discovered the corrosive nature of this acid by observing its effect upon his spectacles, on which some had accidentally fallen, applied it to the purposes of engraving on glass so early as 1670.

substance called borax.* Until lately the nature of its radical was unknown.†

What are the properties of boracic acid?

Boracic acid is in the form of thin scales,‡ slightly acid,§ and unalterable in the air. It forms the variety of salts called *borates*, when combined with the alkalies, some earths, and some of the metallic oxides. One of the peculiar properties of this acid is, that it imparts a green colour to burning bodies.‖

What is ARSENIC *acid?*

Arsenic acid is a compound of arsenic and oxygen. It is a heavy, thick, incrystallizable mass; very soluble in hot water;¶ of an acid taste, and poisonous. With different bases it forms the salts called *arseniates*.

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* The boracic acid was discovered by Homberg in 1702. It may easily be procured by dissolving refined borax in hot water, and adding sulphuric acid till the solution has a slight acid taste. This is then to be left to cool and crystallize.

† See an account of Crell's experiments for the decomposition of this acid in Annales de Chimie, tome xxxv. 202. Sir Humphrey Davy has succeeded in decomposing it by the agency of galvanism, and calls its base boron. It is an opaque, dark olive-coloured, infusible powder. Boracic acid he supposes to consist of about one-third boron and two-thirds oxygen.

‡ This acid, when it is well crystallized, is in the form of small shining flaky crystals. If exposed to a strong heat it becomes fused, and forms a solid white glass, which is sometimes employed in the composition of artificial precious stones.

§ The taste of this acid is bitterish, with a slight degree of acidity. It is very soluble in hot water, and but sparingly so in cold. It is very useful in the analysis of minerals, as it brings almost all the stones into solution.

‖ When burnt with alcohol it communicates a green colour to the flame, which becomes more and more green as the alcohol burns away.

¶ Arsenic acid is not affected by exposure to the air. It is

What is TUNGSTIC *acid?*

The tungstic acid is a tasteless yellow powder, composed of oxygen and tungsten.* It is insoluble in water, but forms the salts called *tungstates*, by its union with alkalies, earths,† or metals.

What is MOLYBDIC *acid?*

Molybdic acid is a pale yellow powder, composed of molybdenum and oxygen.‡ It requires a large quantity of water to dissolve it.§ When combined with salifiable bases, the compounds are called *molybdates*.

What is CHROMIC *acid?*

Chromic acid is an orange-coloured powder,

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composed of 65 parts of arsenic and 35 oxygen. It is made by giving an extra dose of oxygen to the common white oxide of arsenic.

* Tungstic acid is found native in wolfram and other minerals. It may be obtained from wolfram by boiling three parts of muriatic acid on one part of the mineral. The acid is to be decanted off in about half an hour, and allowed to settle: the powder which precipitates is to be dissolved in ammonia; the solution evaporated to dryness, and the dry mass kept for some time in a red heat. It is then yellow oxide, or the tungstic acid in a state of purity. Dr. Thomson, vol. i. 250, 2d edit. This acid becomes blue by exposure to the light.

† Tungstic acid unites with the alkalies to saturation. It dissolves several metals, and assumes a *blue* colour in proportion as it abandons to them a part of its oxygen.

‡ Molybdic acid was discovered by Scheele in 1778. It is procured from the sulphuret of molybdenum by distilling nitric acid off it repeatedly, till the sulphur and metal are both acidified; which is known by the conversion of the whole into a white mass. Hot water carries off the sulphuric acid, and ignition separates the water, and gives the molybdic acid in a state of purity. It requires 960 parts of boiling water to dissolve it. The solution is of a pale yellow.

§ There is another combination of molybdenum and oxygen called the *molybdous* acid, which is in the state of a fine blue powder. For the process of making it, see Sir Humphrey Davy's Elements of Chem. Phil. part i. page 469.

composed of chromium and oxygen. It has an acrid metallic taste, is soluble in water, and crystallizable. When mixed with different saline solutions it assumes a variety of beautiful colours; it also forms with the earths and alkalies various salts, called *chromates*.*

What is the ACETOUS *acid?*

Acetous acid is principally obtained† from saccharine liquors‡ which have undergone the vinous fermentation.§

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* The chromic acid was discovered by Vauquelin. It is procured from the red lead-ore of Siberia. He obtained it by boiling 100 parts of this mineral with 300 of carbonate of potass and 4000 of water, and separating the lead and the alkali by weak nitric acid. For an account of the different colours which this acid assumes, see Dr. Thomson, vol. ii. 105.

† In making vinegar, the casks should be only half filled, that a large surface of the liquor may be exposed to the atmosphere, from whence the oxygen is to be derived to acidify it.

‡ All kinds of wine, and all sorts of malt or saccharine fermented liquors, are capable of yielding *this* acid. The smaller the quantity of the wine, the sooner will it be converted to vinegar, provided there be a free access of atmospheric air. Ample directions for making vinegar will be found in Fourcroy's System of Chemistry, vol. viii. 250: but I believe the best treatise on this subject is by Citizen Parmentier, published in one of the volumes of the Annales de Chimie.

It is found that wine which contains most mucilage soonest becomes acid. On this account isinglass ought not to be added to wines, to fine them, till the moment of bottling them.

§ It was formerly imagined that acetous acid could be prepared only from vinous liquors; but it is not an indispensable condition that it shall have been preceded by the vinous fermentation. This acid may be drawn from wood by the destructive distillation. It is, however, extremely impure, and offensive in its smell, being always intimately combined with a very nauseous empyreumatic vegetable oil: it is called the pyroligneous acid.

Some time ago Vauquelin announced, as a *new* discovery, that pyroligneous acid is identically the same as the acetous;—but this was known to Glauber near 200 years ago. In the folio

What are the properties of acetous acid?

Acetous acid, as it is usually prepared, is a pleasant yellow liquor, well known. When distilled it is as colourless as water, and of an agreeable odour. In both states it is known in commerce by the name of vinegar.*

What is the acid which has been usually called ACETIC *acid?*

Acetic acid is obtained from acetate of copper, acetate of soda, or acetate of potass. It was formerly thought to be the pure acetic acid; but it has lately been demonstrated by experiment to be merely *acetous acid* in a concentrated state.†

What are the properties of acetous acid in this state of concentration?

Acetic acid thus prepared is pungent, acrid, and volatile,‡ and corrodes animal substances.

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edition of his works, page 188, may be seen directions for its distillation, with a copper-plate of the apparatus that he employed. He there calls it the *vinegar* of wood.

According to recent experiments, detailed in a late volume of the Annales de Chimie, it appears that acetous acid exudes with the perspirable matter from the pores of the human body.

* There is so little difference between the volatility of vinegar and water, that it cannot be concentrated by boiling; but if it be mixed with charcoal dust, the charcoal will enable it to resist a strong heat, by which means the water may be thrown off by a boiling heat; and then the pure concentrated acetous acid may be drawn over in a proper apparatus by a stronger heat. We are indebted to Mr. Lowitz for this discovery.

† Darracq has shown that acetous and acetic acid both produced the same combinations, and gave the same products in their decompositions. He brought acetous to the state of acetic acid by distilling it several times over muriate of lime, and then could form as good ether with it as with acetic acid obtained from acetate of copper. Annales de Chimie, tome xxvii.

‡ This acid evaporates entirely when exposed to the air:

With various bases it forms the salts called *acetates.**

What is OXALIC *acid?*

The oxalic is a peculiar acid found in the juice of sorrel, in combination with potass.† The radical of this acid exists also in sugar and in all saccharine substances, and requires only the addition of oxygen to form true oxalic acid. It crystallizes in four-sided prisms, has a very acid taste, and is soluble in water. It is composed of oxygen, hydrogen, and carbon.

What are the uses of oxalic acid?

Oxalic acid is of great use to us in detecting the presence of lime in solution.‡ It is also be-

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and when heated with free access of atmospheric air, it takes fire so readily that one is tempted to suspect the presence of *ether* in it. It dissolves camphor, and, with the addition of essential oils, forms the *aromatic vinegar.*

* Acetic acid may be advantageously employed to separate manganese from iron. When both metals are dissolved in this acid, and the solution evaporated to dryness, the acid adheres to the manganese, but abandons the iron. Water will then dissolve the acetate of manganese from the oxide of iron. Two or three evaporations and solutions are sufficient to deprive acetate of manganese of the whole of its iron.

† Sal-acetosellæ, or the salt of sorrel of commerce, has usually been imported from Switzerland and the neighbouring countries, where it is prepared in large quantities from the juice of sorrel. According to Savary, one hundred pounds of the plant afford five ounces of the crystallized salt.

Deyeux has found a considerable quantity of this acid in chick peas. It was discovered by its burning the shoes of some persons who walked over a field of this pea. There is reason to believe that, by a chemical examination of other plants from which acid liquids spontaneously flow, this acid will be found to exist in greater abundance than has been suspected.

‡ The oxalic has a greater affinity for lime than any other acid; and as it forms with it an insoluble substance, it is the most proper test for discovering this earth. Thus, if a few

come an article of great consumption with the calico-printers, both in a state of purity and in combination with potash.* In combination with earths, alkalies, and metallic oxides, it forms the salts called *oxalates*.†

What is TARTARIC *acid?*

Tartaric acid is a peculiar acid found in the cream of tartar of commerce.‡ It is capable of crystallization, and easily soluble in water. It is used by calico-printers to discharge false prints.§ The salts formed with it are called *tartrates*.

What is CITRIC *acid?*

Citric acid is found in the juice of lemons and

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drops of the solution of oxalic acid be dropped into a neutral solution of muriate of lime, an abundant precipitate of insoluble oxalate of lime will immediately appear. If there be any excess of muriatic acid in the solution, the lime will be re-dissolved. Hence the superiority of oxalate of ammonia, to simple oxalic acid, as a test.

* The calico-printers have attempted to use the acidulous oxalate of potass instead of the citric acid; but it is so insoluble that they find a difficulty in making their solutions of a sufficient strength.

† The oxalic acidule attacks iron, zinc, tin, antimony, and lead. It dissolves also the oxides of all the other metals, and forms with them triple salts. It is employed to take out ink spots from linen, &c. which it does by virtue of its attraction for iron.

‡ Tartar is procured from vessels in which wine has been kept. The tartaric acid appears to be a necessary substance in all wine; for it seems from some late experiments that *must* will not ferment if all the tartaric acid be taken from it. Dr. Thomson, vol. iv. 458.

§ Scheele was the first chemist who obtained tartaric acid in a separate state.

All the vegetable acids seem to be formed from the same radicals, viz. carbon and hydrogen, and perhaps in some there is also nitrogen: the different proportions of these, as well as of the oxygen, constitute the whole varieties.

several other fruits.* It crystallizes in beautiful rhomboidal prisms; is extremely acid to the taste, and very soluble in water. It is used in various ways for domestic purposes, for medicine,† and in the arts.‡ The salts formed with it are called *citrates.*

What is MALIC *acid?*

Malic acid is obtained from the juice of apples, in which it exists ready formed.§ It is a very acid, reddish-coloured liquid, composed, like the other vegetable acids,‖ of oxygen, hydrogen, and carbon. It is capable of crystallization, and has not yet been brought into any use except

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* Scheele was the first person who obtained citric acid from the juice of lemons in a state of purity. When crystallized it suffers no alteration from exposure to the air, though it is said to change after some time when dissolved in water. This acid may be kept ready mixed with either of the dry carbonates of potass or soda; and, as no effervescence ensues till the mixed powder is put into water, we have a ready mode of making a pleasant saline draught.

† Within these few years an important use has been made of this acid in medicine. It is said that the largest dose of opium may be checked in its narcotic effects, if a proper quantity of citric acid be taken with it; and that with this adjunct it induces cheerfulness instead of stupefaction, succeeded by gentle and refreshing sleep. Dr. Willich on Diet, page 339.

‡ This elegant acid is very useful to our manufacturers on account of its solubility. One ounce of cold water will dissolve 1$\frac{1}{4}$ oz. of it, and boiling water will dissolve double its weight. The proper method of procuring it in crystals may be seen detailed in Annales de Chimie, tome xxii.

§ The malic acid is found not only in apples, but in strawberries and other summer fruits. It was discovered by Scheele in the year 1785. For a method of procuring it, consult Dr. Thomson, vol. ii. 160.

‖ Malic acid by the addition of nitric acid is converted to oxalic acid.

as a chemical test.* Its salts are called *malates.*

What is LACTIC *acid?*

Lactic acid is prepared from milk after the curd has been separated. It is incapable of crystallization, and has not hitherto come into use. The salts formed with it are called *lactates.*†

What is GALLIC‡ *acid?*

Gallic acid is found in the galls of commerce, and in most astringent vegetable substances.§ It is obtained in thin transparent plates, and in minute needle-shaped crystals, of an acid austere taste.‖ It has the property of precipitating iron,

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* Malic acid is of use in the analysis of earths for separating alumine from magnesia, as it forms with the former an insoluble salt, which precipitates, leaving malate of magnesia in solution.

† Fourcroy and Vauquelin have asserted, that the acid which is developed in milk is nothing but acetic acid modified by some animal substances and some salts which it holds in solution. Phil. Mag. vol. xxii. 176.

‡ Gallic acid is soluble in 10 parts of cold water, and in 3 of boiling water. It is not altered by exposure to the air, but is decomposable by heat.

§ Gallic acid exists in galls, in oak bark, and other vegetables, independent of the astringent principle. It has been found that the property of giving a black colour to the solutions of iron is owing to this acid, and not to the astringent principles as was formerly supposed. A short process for procuring gallic acid in a separate state may be seen in Crell's Chemical Annals for the year 1787. It was Seguin who proved that the gallic acid and the astringent principle are different substances.

A German apothecary, named Tromer, says that the excrescences on the roots of young oaks may be used with advantage as a substitute for galls. I believe oak saw-dust has been used in this country, instead of galls, to produce a black dye.

‖ Several processes for procuring gallic acid may be seen in Thomson's Chemistry, or in Sir Humphrey Davy's papers in Journal Roy. Inst. and Philos. Trans.

from its solution in acids, of a *black* colour.* Its salts are called *gallates*.

What is MUCOUS *acid?*

Mucous, or saccholactic acid, as it has been called, is obtained by nitric acid from gum arabic and other mucilaginous substances. It is in the form of a white gritty powder, with a slightly acid taste. Its salts are called *mucites*.†

What is BENZOIC *acid?*

Benzoic acid is prepared from a vegetable

For the method of analysing astringent vegetable substances, consult Sir Humphrey Davy's paper in the Philos. Trans. for 1803.

Every substance, an infusion of which precipitates gelatine from its solution, possesses a tanning property. Its presence may be detected thus: Add a few drops of the solution of common glue to a wine-glass full of an infusion of the substance to be examined. If tannin be present the liquor will become turbid, and a whitish substance will precipitate, which is a true powder of leather. A table of the quantity of tan contained in twenty different kinds of bark, showing the comparative value of each to the tanner, may be found in the Philos. Trans. for 1799, drawn up by Mr. Biggin from actual experiments.

Tan has *lately* been employed with success in purifying the common fish and vegetable oils. If any of these oils be boiled with tan, the tan will combine with the substance that occasions their colour and smell, and this latter, being thus rendered *insoluble*, will precipitate.

The gallic acid may be entirely freed from the tanning principle by means of muriate of tin. The tan will unite with the muriate of tin, and form with it an insoluble precipitate. There is reason to believe that tan is the source of the astringent principle in all astringent vegetables.

* Gallic acid will not immediately give a black colour to green sulphate of iron in dyeing black, or in making ink. Exposure for some time to atmospheric air is necessary, in order that the iron may thereby acquire a further dose of oxygen. A few drops of oxygenized muriatic acid will instantly produce the effect.

† Mucous acid was discovered by Scheele in the year 1780: for the method of obtaining it consult Dr. Thomson, vol. ii. 151.

resin called benzoin.* It is a light whitish powder, with a peculiar and aromatic odour. Its taste is acrid and bitter. It is unalterable in the air, insoluble in cold, but soluble in boiling water.† It is used in medicine under the name of flowers of benjamin.‡ Its salts are called *benzoates*.

What is SUCCINIC *acid?*

Succinic acid is prepared from amber.§ It takes the form of shining white crystals, of a slight acid taste. It sublimes in a great heat.‖

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* Benzoin is a resin procured from a tree which grows in the island of Sumatra. The acid procured from this resin has been known for 200 years. It is obtained from benzoin, in the form of flowers, by sublimation.

This acid is found also in balsam of Tolu, Peruvian balsam, liquid storax, and other similar substances. It has been likewise discovered in the urine of children, and of graminivorous animals; in blood; and in some of the species of fungi.

Vauquelin advises the collection of the urines of cattle, as proper for furnishing economically the benzoic acid. He recommends the decomposition of it by the muriatic acid.

† Benzoic acid may be procured by boiling the resin with carbonate of soda, and adding to the filtered decoction diluted sulphuric acid as long as it produces any precipitation. The precipitate which forms, is the benzoic acid.

‡ The best flowers of benzoin are of a brilliant white, entirely soluble in alcohol, and likewise, though more sparingly, in boiling water, and leave no ashes when evaporated by heat.

§ Amber is a transparent combustible substance, dug out of the earth, or found upon the sea coast. It manifests electricity by friction, and was much admired by the ancients as an ornament of dress. The amber-pits of Prussia are said to afford the king a revenue of 36,000 dollars annually.

‖ Succinic acid may be obtained thus: Fill a retort half way with equal parts of powdered amber and dry sand; lute on a receiver, and distil in a sand bath with a gentle heat. The succinic acid will attach itself to the neck of the retort. It is generally coloured by a portion of oil which comes over in distillation; but it may be purified by pouring nitrous acid upon

It is soluble in hot, but dissolves in small quantities in cold, water. It is useful as a re-agent,* but of no use in the arts. Its salts are called *succinates.*

What is CAMPHORIC *acid?*

Camphoric acid is prepared from camphor by means of nitrous acid.† It is in very white crystals, which have a slightly acid, bitter taste, and a smell like saffron. It is very insoluble, requiring nearly 200 times its weight of water to dissolve it. With salifiable bases it forms *camphorates.*

What is SUBERIC *acid?*

Suberic acid is formed from cork, by means of nitrous acid.‡ Its taste is acid; it is generally seen in the state of powder, and is not crystallizable. Boiling water dissolves half its

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it, and then expelling the nitrous acid by a heat not sufficient to drive off the succinic acid.

* When combined with ammonia this acid becomes a valuable re-agent, by the property of separating iron from its solutions, and not operating upon other metals. Thus, if a little of this succinate of ammonia be added to a solution of sulphate of iron, a succinate of the metal will be precipitated. It may be calculated that every 100 grains of the precipitate contain 68 grains of iron.

† Camphor is a white crystalline substance, of a very strong taste and smell, obtained in the East from a species of laurel. It is so inflammable that it burns even on water. La Grange's different processes for preparing this acid are translated by Mr. Nicholson, and published in vol. ii. of his Journal, 4to.

‡ This acid was discovered by Brugnatelli, in the year 1787. He gave it the name suberic acid from *suber*, the Latin name of the cork-tree. This chemist has lately noticed that suberic acid in considerable quantities may be obtained from paper, by treating it with nitric acid.

weight, but it is very insoluble in cold water. Its salts are called *suberates*.

What is LACCIC *acid?*

Laccic acid is procured from a substance called *white lac*.* It has a bitter saltish taste, but not at all sour.† It crystallizes in needle-like crystals.

What is PRUSSIC *acid?*

The prussic is a peculiar acid, composed of hydrogen, nitrogen, and carbon. It is a colourless liquid like water, has a sweet taste, and does not alter the colour of vegetable blues. It is of great use to chemists for detecting metals in solution.‡ It is prepared from blood and other animal substances;§ and when united with *iron*, forms that beautiful colouring substance called Prussian blue.‖

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* White lac is a peculiar substance brought from the East Indies. This substance, which has a resemblance to bees'-wax, is secreted by an opaque and rough insect, of a gray colour.

† Laccic acid was discovered by Dr. Pearson. It is generally in a fluid state. Its specific gravity at 60° is 1.025, and when heated it has the smell of newly baked bread.

‡ The colour of the precipitate indicates what metal, and its quantity enables us to ascertain the proportion of such metal contained in the solution to be examined. For this purpose the acid must previously be combined with an alkali or an earth. Prussiate of potass is generally used.

§ A method of obtaining prussic acid in a state of absolute purity has lately been announced: it is merely by distilling a mixture of two parts of prussian blue, one of sulphuric acid, and one of water.

There is great reason for believing that prussic acid does not contain oxygen. The grounds on which this supposition is founded may be seen in Berthollet's Chemical Statics, vol. ii. 222.

‖ Prussian blue was discovered by accident in the year 1709;

What is SEBACIC *acid?*

Sebacic acid is procured from animal fat or tallow. It has an acid, sharp, bitterish taste.* It combines with alkalies, earths, and metallic oxides, and forms the salts called *sebates*.

What is URIC *acid?*

The uric or lithic acid is found in human urine.† Some of the human calculi are composed entirely of this acid. It has neither taste nor smell, but it reddens vegetable blues, and combines with alkalies and earths. It is a com-

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but it was not till the year 1775 that Bergman ascertained that this colouring matter was a peculiar acid. Scheele, however, was the first who explained its nature and composition, in the year 1782, announcing that he had formed it without animal matters, and that it is a compound of ammonia and charcoal. Later experiments of Berthollet show that this acid does not contain ammonia ready formed, but that is a compound of carbon, hydrogen, and nitrogen.

The process to prepare prussian blue may be seen in Neumann's Chemistry, vol. i. 106; in Shaw's Lectures on the Arts, 8vo, 160; or in Bouillon La Grange, vol. ii. 354. The Journal de Physique for the year 1778 describes the process as it is conducted in the manufactories of Germany.

* Sebacic acid crystallizes in needles, and when heated liquefies like tallow. For further information consult Nicholson's Journal, vol. i. 8vo, 34; and Thenard's memoir in Annales de Chimie, tome xxxix. 193.

† If urine voided in the morning after sleep be preserved, the liquor will in a few hours present a light cloud, which occupies the upper part of the vessel; this cloud, gradually augmenting in quantity, subsides, and becomes a sediment of small red crystals, with brilliant facets: this is *uric acid*.

Nitric acid is a test for discovering uric acid. If a little uric acid be heated in a watch-glass over a lamp, the smallest quantity of nitric acid that can possibly be conveyed upon it will instantly convert it to a very brilliant crimson.

position of carbon, nitrogen, hydrogen, and oxygen.

What is the AMNIOTIC *acid?*

Amniotic acid is obtained from the liquor of the amnios of the cow. It is slightly acid; it reddens the tincture of turnsole; and may be obtained in white crystals.*

How many different distinct acids are there?

The whole of the acids now known amount to about thirty, besides what are formed by some of those acids combining with different proportions of oxygen.†

What are the USES *of these various acids?*

The uses of the acids are so many and im-

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* The amniotic acid was discovered by Vauquelin and his coadjutor Buniva. It dissolves readily in hot water, and but slow and sparingly in cold. In order to obtain it, nothing more is necessary than to evaporate the liquor of the amnois of the cow to one-fourth, and leave the remainder to cool, which will be found to contain the acid in crystals.

The MELLITIC and the COLUMBIC acids I have omitted to describe, because the minerals from which they are procured are so rare, that few chemists will ever be likely to obtain even a specimen of them.

† The acids are such powerful agents in a variety of chemical changes which take place in nature and in the arts, that it is of the utmost importance to acquire a knowledge of the modes in which they operate. Let it be recollected, then, that there are two ways in which the acids produce changes in the substances with which they are brought into contact. In some cases they effect an union with these substances, and become a part of the new compound, without having themselves undergone any decomposition. In others they become partially decomposed, by affording a part of their oxygen to the bodies on which they operate. The formation of common salt by the union of muriatic acid with soda is an instance of the first of these cases, and the action of nitrous acid on iron will exemplify the latter.

portant, that it is impossible to enumerate them. They are indispensable to various arts* and manufactures;† they are employed for culinary purposes,‡ and for medicine:§ they act an im-

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* Sulphuric acid, in a diluted state, is used by the tanner in the operation called scouring; also by the dyer, in a concentrated state, for dissolving indigo. It is likewise employed by hatters. Silk-dyers use it for whitening silks, and for giving them a beautiful lustre. The chemist employs it in the preparation of nitrous and muriatic acid, and as an agent in a variety of processes and decompositions.

Nitric acid is used by dyers to make their solutions of tin. Silver-refiners employ it in the operation of *parting*. It is also used by gilders, brass-founders, calico-printers, colour-makers &c.

Muriatic acid is employed in dyeing, calico-printing, and colour-making. The oxymuriatic acid, in bleaching, and in medicine.

† The acetous, oxalic, tartaric, citric, gallic, and prussic acids are all of them employed in the different manufactures of the country.

‡ The acetous, the tartaric, and the citric acids are used for culinary purposes. According to some experiments of Dr. Macbride, it appears that all the mineral acids in a diluted state might be employed with great advantage in preserving meat. They probably owe their antiseptic qualities to oxygen. Muriatic acid drawn in glass would, I believe, in a state of great dilution, be a pleasant and wholesome condiment for our food. It was formerly used in this way. The celebrated Rudolph Glauber, who was the first to turn the residuum which is left after the distillation of this acid to a good account, describes the several ways in which it was used in the kitchen in his time, page 12 of his Treatise on Philosophical Furnaces. That this acid possesses valuable antiseptic qualities there can be no doubt. Sir William Fordyce gives an account of a dry-salter who acquired a large fortune from possessing a secret, that had enabled him to send out to the Indies provisions in a better state of preservation, than any others of the trade. His whole secret was that of putting a small quantity of muriatic acid into each cask.

§ Great advantages have already been obtained from the use of many of the acids in medicine, particularly the sulphuric,

portant part in the great elaboratory of nature,—they produce that numerous class of bodies called salts, and form a great proportion of many of the rocky and mountainous districts of the globe we inhabit.

Do you recollect any instances of acids entering into the composition of rocks and mountains?

The vast masses of limestone, chalk, and marble, which are found in every part of the world, are combinations of lime and carbonic acid:* the mountains of gypsum in the vicinity of Paris and elsewhere are combinations of lime and the sulphuric acid.† The fluor spar of Derbyshire owes its compactness, &c. to the fluoric acid;‡ and there are masses of common salt, both in the eastern and western hemi-

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nitric, and muriatic acids. "As to the *oxymuriatic acid*," says Fourcroy, I will venture to affirm that it will hereafter be one of the most useful of the materia medica.

Parliament voted a reward of 5000*l.* to Dr. Carmichael Smith, for his discovery that nitrous acid, applied in the state of vapour effectually destroys contagion, especially typhus, jail, yellow, and such like fevers. The most simple process for this purpose is that invented by Mr. Hume, who assisted the Doctor in his experiments. See Smith on Nitrous Vapour.

Dr. Thornton says that he has cured syphilitic complaints by nitrous acid, in cases where mercury has failed. Medical Extracts, vol. v. 406. Mr. Cruickshank, of Woolwich, has given it with the same intention, and with the best success.

* Limestone, chalk, and marble, are composed of about 50 parts acid and water, and 50 parts lime.

† Gypsum is composed, according to Bergman, of 32 parts of lime, and 68 of acid and water.

‡ There are, however, some varieties of fluor spar which contain different portions of acid.

sphere, which contain hundreds of millions of tons of muriatic acid.*

Are you sure that the acids which Nature has employed in the formation of mountains are of the same kind as those which come under our common notice and observation?

Yes: any of these substances may be decomposed, and their acids exhibited in a state of purity for experiment or use.†

Do you know of any other natural productions, which are indebted to the acids for their natures and properties?

The large masses of alum ores and of ponderous spar in different parts of the earth owe their origin to the sulphuric acid; the cryolite of Greenland is a compound of alumine and the fluoric acid; and several of the precious stones are combinations of the different earths with the chromic or the phosphoric acids;‡ not to men-

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* Common salt, according to the analysis of Kirwan, is composed of 53 parts soda, 39 acid, and 8 water.

† If the pupil be directed to pour a little diluted sulphuric acid upon some pieces of marble, the carbonic acid will be disengaged and become evident to the senses. In like manner he may disengage the fluoric acid from the fluor spar, the muriatic acid from rock-salt, and other acids from those minerals in which they are found native. A few experiments of this kind will serve to show him how abundantly the mineral acids occur in nature.

‡ Vauquelin thinks that the emerald owes its colour to the *oxide* of chrome, and the ruby to the *acid* of that metal. According to this chemist, the ruby is a combination of the chromic acid, alumine, and magnesia. Ann. de Chim. tome xxv.

The chrysolite seems to be composed of lime and the phosphoric acid. See Ann. de Chim. tome xxvi.

the annual changes which the vegetable king-
undergoes by the formation and loss of the
table acids.

ou speak of the formation of acids:—Are bodies
is class formed and decomposed by the common
utions of nature?

any of these bodies are not only formed ar-
ally, by the direct union of their radicals
oxygen, but we have reason to believe that
is perpetually done by natural means; and
the acids are the principal agents in those
nical changes which the various substances of
earth are destined to sustain.*

Mr. Baumé, by a series of ingenious experiments, dis-
ed that clays may be produced by the action of the sul-
acid on vitrified substances. Mr. Ferber applied this

CHAPTER VIII.

OF SALTS.

WHAT is a salt?

When an acid is combined with an alkali, an earth, or a metallic oxide, it forms what is called *a salt.* Such compounds were formerly called *neutral* salts; but that term is now applied only to those salts in which there is no excess either of acid or of base.

How many salts are there?

As the acids are capable of forming various combinations with the different earthy, alkaline, and metallic bases, the precise number of the salts is not known.† Probably they amount to nearly two thousands.‡

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* To give the pupil a clear idea of this class of bodies, it may be advisable to set him to form some of the salts from their component parts. He might be directed to pour a little sulphuric acid into a solution of soda in water, to evaporate the superfluous water, and then to notice the crystallization of the new-formed salt: if the liquor be allowed to stand quietly for a few hours in a cool place, the salt will be seen to shoot into beautiful crystals of sulphate of soda.

† Fourcroy reckons that there are 134 *species* of salts; but how many distinct salts there are he has not calculated.

Having 32 acids and 57 bases, it would appear at first sight that there must be 1824 salts: but there are several of the metallic oxides which cannot combine with many of the acids; which is also the case with silex, one of the earths. However, to compensate for this deficiency, there are several acids capable of combining with two bases at once. These are called *triple-salts.* Besides these there are super-salts, and sub-salts.

‡ Should any one express his surprise that the number of

What method has been taken to distinguish the different salts?

Modern chemists have adopted a new nomenclature for this purpose, which is as simple and ingenious as it is useful.*

How are the salts distinguished by this means?

In this nomenclature every salt has a double name, one part of which indicates its acid, and the other its base; so that, in a collection of many hundred different salts, the composition of each is immediately known by its appellation.†

Can you explain the manner in which this is effected?

All substances which are compounds of metallic oxides, earths, or alkalies with the sulphuric acid, are called *sulphates;* with the muriatic acid, *muriates;* with the nitric acid, *nitrates;* with the carbonic acid, *carbonates*, &c. &c.‡

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one class of bodies should be so great, he may be told that Nature seems to aim at variety in all her productions. Saint Pierre informs us that there are 6000 species of flies, and 760 different butterflies. Ray computed the number of species of insects at ten thousand. There are above 1000 different species of beetles in Great Britain.

* This nomenclature was drawn up by a society of French chemists, soon after the new theory of chemistry was announced by Lavoisier; the foundation of which was already laid by the previous discoveries of Dr. Black, Dr. Priestley, and Mr. Cavendish.

† Fourcroy has well remarked, that, if this arrangement had not been made, it would have been absolutely impossible to know the characters of the numerous salts which have been discovered, and the science of chemistry would then have been confined to the very few men who are capable of extraordinary efforts of memory.

‡ These are the terms generally made use of in chemical

Do the advantages which we derive from this nomenclature compensate for the inconvenience of changing the names of so many substances?

The new nomenclature, by its scientific classification of bodies, gives such a facility to the acquisition of chemical knowledge, that this alone would have been sufficient to have justified chemists in adopting it; but its contrivance for pointing out the *nature* of the substances bearing the new names, gives it advantages far surpassing every inconvenience attending the alteration.*

Describe the nature of some of these advantages.

In conformity with this plan the saline compound, formerly called *Glauber's* salt, is now called sulphate of soda, for it is a combination of sulphuric acid and soda; what was called *gypsum*, or plaster of Paris, a compound of lime and sulphuric acid, is now called sulphate of lime;

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language; but sometimes, in order to prevent monotony, we give an adjective termination to the word which expresses the base of the acid. Thus we say calcareous salts, instead of salt of lime; ammoniacal salts, instead of salts of ammonia; aluminous salt, instead of salt of alumine; and with the same design, the terms barytic, magnesian, and the like are used.

* As the boundaries of chemical science have been extended, the number of known salts has been surprisingly increased; so much so, that it would have been impossible to recollect the nature of each, without the assistance of a nomenclature of this kind. Thirty years ago not more than 20 or 30 species were known; since then more than 100 new species comprising upwards of a thousand distinct salts, have been added to the list.

† It is necessary to remark, that when an acid is combined with *two* bases, the names of both are subjoined to that of the acid. Thus we say sulphate of alumine and potass, and tartrate of potass and soda.

in like manner, what was called *green copperas* is now sulphate of iron, that substance being a compound, not of copper, as the old name seemed to import, but of *iron* and sulphuric acid.*

Have the framers of this nomenclature been equally happy in the choice of names for the salts which are composed with the other acids?

Yes; the principle upon which the nomenclature is formed is such, that the composition of every salt is designated by an appropriate name with the utmost perspicuity.†

According to the new nomenclature, what is the common culinary salt called?

Common salt is called *muriate of soda*;‡ that is, a composition formed of soda and muriatic acid.

What do you call salt-petre?

Salt-petre is called *nitrate of potass;* it being composed of potass and nitric acid.

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* It would be easy to make out a long list of substances with names equally improper with those noted above, and which have characteristic and appropriate names now assigned them in the new nomenclature.

† I would advise those who may be desirous of learning this nomenclature to form some of the salts from their component parts, as directed in the first note of this chapter; to register the proportions of the materials employed; and to lay them up, with labels of their proper chemical names affixed to them. This will infallibly imprint the connexion between the nature of these salts and their modern names, upon the mind; and the practice should be continued till the pupil has a clear idea of the principle on which the whole nomenclature is founded.

‡ Formerly the word SALT was confined to muriate of soda. No other substance was then known as a salt. Afterwards, the acids and alkalies were called salts also. There are innumerable proofs of this in the old chemical writings.

What is chalk now called?

Chalk, being a compound of lime and carbonic acid, is called *carbonate of lime.**

You have said that these bodies were formerly called neutral salts,—why is not that term now applied as before?

No salt can strictly be called *neutral*, except such in which the acid is completely neutralized by the base, and the base by the acid, so as to be mutually saturated by each other.†

Is not that the case with all saline compounds?

No: some have an excess of acid, as cream of tartar and most of the metallic salts; others have an excess of base, as common borax.

How are such salts distinguished?

When a salt is found to contain an excess of acid, the preposition SUPER is generally prefixed to its name:‡ but when it does not contain a sufficiency of acid to saturate the base, the preposition SUB is added: thus we say super-tartrate of potass, and sub-borate of soda.§

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* The calcareous crystals; the marbles; and the common limestones, are also all called carbonates of lime.

† The propriety of restricting the use of the term *neutral* will appear, if we consider that we have some bases that combine with more than one dose of acid, and thereby form salts which differ in their appearance and properties. Thus we have *sulphate* of potass, and *super*-sulphate of potass. The one is a neutral salt, the other a salt with excess of acid.

‡ Many of these super salts may be discovered by carbonate of magnesia. If an acid be present in the solution, an effervescence will take place on the addition of the carbonate.

§ We are indebted to Dr. Pearson for this mode of distinguishing these salts. Before his method was adopted, the former of these salts was called tartrate of potass with excess of

Some salts are formed with acids not fully oxygenized, as the sulphurous and phosphorous acids: how are such salts distinguished?

All salts that are composed with acids ending in *ous*, take an ending in *ite*, instead of *ate;* as *sulphite* of lime, or *phosphite* of potass.*

* * * * * * * *

Having shown the nature of the present chemical nomenclature as far as respects the salts, it will now be necessary to enter on the consideration of each genus separately:—Therefore, What are the generic characters of the SULPHATES?

The sulphates† have generally a bitter taste; are always decomposed by the agency of a solution of barytes; and afford sulphurets when heated red-hot with charcoal.‡

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acid, or acidulous tartrate of potass; and the latter, borate of soda with excess of base.

* When sulphur is fully saturated with oxygen it forms what is called sulphuric acid, and the salts composed with this acid are called sulphates. But when sulphur is partially oxygenized, an acid is produced called sulphurous acid, and the salts formed with it are called sulphites.

The new nomenclature enables us to distinguish between acids which are partially oxygenized, and those which contain a maximum of oxygen. This is of great importance, because the properties of the salts formed with these acids vary as much as the acids themselves. The salts formed with acids ending in *ic* are generally permanent; whereas salts formed with the same bases combined with acids ending in *ous* are seldom permanent, but by exposure to the air attract oxygen, and are changed into salts of the former kind.

† The quantity of sulphuric acid contained in any of the sulphuric salts may be known by means of barytes. For, if any of the solutions of this earth be added to a solution containing sulphuric acid, a sulphate of barytes will instantly be formed and precipitated, and every 100 grains of the precipitate when dried indicate 34 grains of sulphuric acid.

‡ When a sulphate has been converted to a sulphuret by

Can you enumerate a few of the principal sulphuric salts?

Among the first of them are: sulphate of barytes,* sulphate of strontian, sulphate of potass, sulphate of soda, sulphate of lime,† sulphate of magnesia, sulphate of ammonia, and sulphate of alumine.‡

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burning with charcoal, the sulphuret may be decomposed, and the sulphur precipitated by the addition of muriatic acid. For a method of decomposing these salts in a large way consult Encyclopædia Britannica, Chemical Index, article *Vitriolated Tartar*.

To analyse the earthy sulphates, heat them to whiteness, in order to find the quantity of water which they contain; then boil them with carbonate of potass, which will occasion their decomposition. A common Florence oil flask is sufficient for this purpose. It may be ascertained when it has been sufficiently boiled by taking a little of the earth from the bottom of the flask, and trying it with muriatic acid. If the muriatic acid dissolves it entirely, the decomposition is complete.

* Sulphate of barytes, or *ponderous spar* as it has been called, is abundant in different parts of the earth. Sulphate of strontian is found in Scotland and elsewhere in abundance. Sulphate of potass, sulphate of soda, and sulphate of ammonia are prepared by chemical manufacturers in many of their processes. Sulphate of lime, sulphate of magnesia, and sulphate of alumine are native productions. Sulphate of ammonia, it has been said, has been found native in the neighbourhood of volcanoes.

† Sulphate of lime is gotten in abundance in Staffordshire, Derbyshire, and other counties of England. The hills around Paris are composed entirely of this earthy salt. Hence its name *plaster of Paris*. When burnt and ground it is miscible with water, for which it has so great an affinity that it becomes solid almost immediately. This property renders it an excellent substance for forming busts, cornices, &c. which are very durable, if protected from the weather, and not exposed in damp situations. In America this substance has been long used as a manure; it is coming into use in this way, also, in some districts in England.

‡ Alum is prepared near Glasgow, by Messrs. Mackintosh and Knox, at a much less expense than it can be made at Whitby, as it is there found ready formed in a state of silky efflorescence, and only requires to be dissolved and crystallized for sale. It seems that a large quantity of aluminous schist was laid bare by the working of a coal pit, at least 200 years ago;

strontian, of lime, of ammonia, and the muriate of magnesia.*

What are the generic characteristics of the HYPEROXYMURIATES?†

The hyperoxymuriates yield very pure oxygen gas by the action of fire, and are thus converted to common muriates: and the stronger acids expel the hyperoxymuriatic acid from these salts, without the assistance of heat.‡ When mixed

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le Goux, in his history of the cocoa-nut tree, tells us that the inhabitants of those parts of Hindostan and China which border on the sea-coast sprinkle their rice-fields with sea-water, and use no other manure; and that in the interior of these countries they sprinkle the lands with salt before they are tilled; and that this practice has been followed for ages with the greatest advantage.

In a conversation with a gentleman who has spent many years of a valuable life in making experiments on the employment of salt in agriculture, and in endeavouring to procure an act of parliament to sanction its use, I was informed that one bushel to an acre makes land always more productive; but that a large quantity would for 2 or 3 years afterwards render it actually steril.

* Muriate of potass has been found native in the bogs of Picardy. Muriate of ammonia is the common sal-ammoniac of commerce. Muriate of barytes and strontian are both factitious salts. Muriate of lime is found native in various states; it is used for the production of artificial cold. When dissolved in alcohol it burns with a flame of a beautiful red colour, especially if the solution be agitated during the inflammation. Muriate of magnesia is found in mineral and in sea-waters.

† The hyperoxymuriates were discovered by Berthollet in 1786; but the gas from these salts was discovered by Sir Humphrey Davy in a *pure state* in January, 1811. See his Elements of Chemical Philosophy, vol. i. page 238. He calls it *Euchlorine*.

‡ Those salts which have been called oxymuriates, Mr. Chenevix calls hyperoxymuriates. He was desirous of exhibiting the acid in a separate state: but when he attempted to obtain *it from only* 500 grains of hyperoxymuriate of *potass*, the *retort burst* with a loud report, and was reduced almost to a pow-

visible form of vapour; and when by the nitric acid, oxymuriatic gas. They are the most volatile, and yet the least decomposable by fire of all the salts; not being perceptibly altered by combustibles, even when assisted by heat.*

Can you enumerate the chief of the muriatic salts?

The principal salts in the muriatic class are, the muriates of barytes, of potass, of soda,† of

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alkaline and earthy bases with sulphurous acid. For the easiest method of conducting the process, consult Thomson's Chemistry, vol. ii. 449.

* This is an evident, and, at the same time, a most remarkable character of this species of salt. Muriate of soda may be volatilized by heat, but if the vapour be collected it will be found still to be muriate of soda. Some years ago I exposed several hundred weights of this salt to a most intense heat in a reverberatory furnace for 48 hours, with a view to decompose it; but when it was removed from the furnace there was no change, it remained muriate of soda. Another portion was kept in a state of fusion for 36 hours with a considerable quantity of carbonaceous matter, but no decomposition was effected.

† Muriate of soda is the salt which has been longest known. It is our common culinary salt, and is supposed to furnish the necessary supply of soda to preserve the bile in an alkaline and antiseptic condition.

This salt is of great use to the animal creation; horses are very fond of it; and cows give more milk when supplied with it. Dr. Mitchill relates, that in the back settlements of America, wherever this salt abounds, thither the wild beasts of the forests assemble to regale themselves; and that some of these places are so much frequented, that the ground is trodden to mud by them. The natives call these spots *licks*, or licking-places. In some parts of Africa, large herds of cattle travel from great distances at stated seasons to enjoy the marine plants which grow on the coast, and are saturated with sea-salt. The fattening property of our own salt-marshes is well known to graziers and farmers.

Whenever the finances of this country are in a state to allow the duty to be withdrawn, the greatest improvements in agriculture may be expected from the use of sea-salt. Mr.

What are the generic characteristics of the NITRATES?

The nitrates yield oxygen gas mingled with nitrogen gas by the action of fire; they give out a white vapour of nitric acid when acted on by concentrated sulphuric acid; and, when mixed with combustible substances, produce, at a red heat, inflammation and detonation.*

Can you enumerate some of the nitric salts?

The more noted are; the nitrates of potass,†

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manufacture of gunpowder. The attempt was made; but no sooner did the workmen begin to triturate the mixture than it exploded with violence, and proved fatal to two individuals who were near it. Phil. Trans. xcii. 128. I have, however, reason to believe that gunpowder made with this salt was afterwards actually used by the French in one of their campaigns. See Additional Notes, No. 56.

A solution of this salt well mixed with common soap in a mortar, is said to improve the soap so as to render it fitter for shaving than any of the kinds recommended for that purpose.

The other hyperoxymuriates are also prepared by art, and are of little use, except the HYPEROXYMURIATE OF LIME, which is employed in bleaching. This article is generally considered the best that has ever yet been introduced for that purpose; but Sir Humphrey Davy recommends the hyperoxymuriate of magnesia in preference to it. See his new work, page 243.

* This may be shown by heating a little nitre in a crucible, and throwing powdered charcoal upon it. The charcoal will combine with the oxygen of the nitrous acid, and pass off in the state of carbonic acid gas.

† Nitrate of potass (salt-petre) is generated by nature in abundance, particularly in the East: in some districts it appears in an efflorescence on the surface of the soil, from whence, at a certain season of the year, it is regularly swept off two or three times a week, and as repeatedly renewed: it appears that nothing is necessary for its production but the presence of lime, animal and vegetable matters, heat, and dry atmospheric air. The atmosphere furnishes the acid: but how the potass occurs in it, is not known.

Notwithstanding the prodigious quantity of salt-petre col-

of barytes, of soda,* of strontian, of lime,† of magnesia, and of ammonia.

What are the generic characteristics of the CARBONATES *?*

All the alkaline carbonates are soluble in water, while those of the earths and metals are nearly insoluble, unless the acid be in excess; and they

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lected in the East Indies, it has been calculated, that two thirds of the whole are annually sent into China and other parts of Asia to make artificial fire-works. The fire-works of the Chinese exceed those of all other nations in variety and beauty.

At Apulia near Naples there is a natural nitre-bed, in which the earth contains 30 per cent. of nitre. Pelletier has published a memoir on the analysis of this valuable treasure, in the Annales de Chimie, tome xxiii.

In Switzerland, the farmers extract an abundant quantity of very fine salt-petre from the earth under the stalls of their cattle. The urine of quadrupeds contains much potash, and this acquires nitric acid from the atmosphere. See Additional Notes, No. 22.

In the reign of Charles the First, great attention was paid to the making of *salt-petre in England*. Certain patentees were authorized by royal proclamation to dig up the floors of all dove-houses, stables, &c. the proprietors at the same time being prohibited from laying such floors with any thing but mellow earth.

Nitre is used in large quantities in the manufacture of gunpowder, every 100 parts of which are composed of 76 parts nitre, 15 charcoal, and 9 sulphur. The best account we have of this manufacture was published by Mr. Coleman, a superintendant of one of the royal powder-mills, in the Phil. Mag. vol. ix. 355.

* Nitrate of soda, according to Bowles, has been found native in Spain.

† Nitrate of lime is generally found native with salt-petre, and in the greatest proportion. This salt, if properly heated, becomes luminous in the dark, and forms what is called Baldwin's phosphorus. In India, where this salt occurs in abundance, the salt-petre makers lixiviate wood ashes with the soil. This gives them nitrate of potash, or salt-petre instead of nitrate of lime.

all effervesce, and give out the carbonic acid, when treated with the stronger acids.*

Endeavour to enumerate the principal carbonates, or bases combined with this acid.

The carbonates of barytes,† of strontian, of lime,‡ of potass, of soda, of magnesia, and of ammonia, are the principal salts of this class; and that of lime is probably the most abundant in nature.

What are the generic characteristics of the PHOSPHATES *?*

The phosphates are fusible either into opaque or transparent glasses; are phosphorescent at a high temperature; are soluble in nitric acid without effervescence; and are precipitable from their solutions by lime-water.

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* There are eleven species of carbonic salts at present known. There are, however, only four of the native earths found combined with this acid, viz. lime, barytes, strontian, and magnesia.

Crystallized carbonate of lime may be known by its lightness, and by being found in rhomboids. Its specific gravity is only 3.00, being the lightest of all the earthy salts.

† Carbonate of barytes was discovered by Dr. Withering in 1783. It is not so scarce and dear as it was formerly; and, from its superior affinity, may become a most useful article in the arts. The carbonate of strontian was found at Strontian by Dr. Hope. Carbonate of lime exists in great abundance in all countries and under an extensive variety of forms. The other carbonates are in general formed artificially.

‡ Carbonate of lime is not soluble in water, unless the water itself be charged with carbonic acid: it is by this means that Nature effects a solution of calcareous masses, to form stalactites, and other beautiful incrustations. See page 134.

§ The only phosphoric salt which is found native is the apatite, or phosphate of lime, which occurs in abundance in many parts of the world.

Which are the chief phosphoric salts?

The phosphates of lime,* of soda,† and of ammonia,‡ and the phosphate of soda and ammonia, formerly called microcosmic salt.§

What are the generic characteristics of the PHOSPHITES?

The phosphites yield a phosphorescent flame

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* Phosphate of lime is found in bones, milk, and some other animal matters. It is white, tasteless, and insoluble in water. Entire mountains in Spain are formed of this salt. It is composed of phosphoric acid 41 parts, lime 59. It is prescribed by the French physicians as a specific in the rachitis, to diminish the effects of acids which soften the bones. Fourcroy, vol. iii. 346. See also Bonhomme's paper on this subject in Annales de Chimie, tome xvii.: the cases which he adduces are extremely curious.

Phosphate of lime exists also in the farina of wheat. La Grange remarks, that a person who eats a pound of farina a day will swallow 3 pounds 6 ounces 4 drams and 44 grains of phosphate of lime in the year. It is a curious fact, that the grain of wheat should contain *phosphate* of lime, while the straw, which was *not* intended for our food, should contain *carbonate* of lime only.

It is remarkable, that though phosphate of lime is always found in the urine of adults, this salt is not evacuated by infants. The rapid formation of the bones, in the first periods of life, requires that there should be no waste of any of the phosphoric salts; and Nature, ever provident, has provided accordingly.

† Phosphate of soda is formed artificially. It was first made and recommended by Dr. Pearson. This salt is used in medicine as a cathartic, and is much pleasanter than either Glauber or Rochelle salts. It forms very distinct crystals; and is used by some manufacturers as a flux, instead of borax.

‡ Phosphate of ammonia is found in urine, and is also prepared by art to be used as an ingredient in making pastes, to imitate precious stones. It is one of the best fluxes for experiments with the blow-pipe.

§ Phosphate of soda and ammonia is found in human urine, from whence it may be procured by evaporation in the state of a triple salt.

when heated;* and in a strong fire give out a portion of phosphorus, by which they become converted into phosphates.† By a very strong heat they are fusible into glass.

Endeavour to enumerate the principal phosphites.

The chief of them are, the phosphites of lime, of barytes, of potass, of soda, and of ammonia.‡

What are the generic characteristics of the FLUATES?

The fluates are weak salts, yielding, by means of concentrated sulphuric acid, a vapour which corrodes glass, and which, when condensed in water, forms liquid fluoric acid. They are not decomposable by mere heat, nor altered by combustibles.

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* None of the phosphites have been found in nature; they are all formed artificially, by saturating the different bases with phosphorous acid, either directly, or by means of double decomposition. None of them have yet been brought into use. Fourcroy distinguishes eleven species of the earthy and alkaline phosphites.

† The affusion of nitric or oxymuriatic acid will also convert these phosphorous salts to phosphates.

‡ Phosphite of ammonia exhibits several curious appearances when treated with caloric. For all the particulars, consult Fourcroy, vol. iii. 405. If heated on charcoal by means of a blowpipe, it boils, and loses its water of crystallization; it then becomes surrounded with a phosphorescent light, and bubbles of phosphuretted hydrogen gas are emitted, which burn in the air with a lively flame, and form a fine coronet of phosphoric acid vapour.

§ The fluates were first made known by Scheele in 1771. Some of them phosphoresce when heated.

Which are the chief fluoric salts?

Fluate of lime,* fluate of soda, fluate of ammonia,† fluate of alumine, and fluate of silex.

What are the generic characters of the BORATES?

The borates are all fusible into glass, and, with most of the metallic oxides, form glass of different colours.‡ Concentrated solutions of

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* Ten varieties of fluate of lime have been found. They are of different colours, owing to the different degrees of oxidizement of the iron which they contain. If any of these coloured fluates be pulverized, and then heated on a shovel, they will emit a very curious violet-coloured phosphoric light, the cause of which is not known. We have no means of dissolving fluate of lime in water: but Nature dissolves it by some unknown process; for it is found in crystals, combined with its water of crystallization. This crystalline substance is known by the names of Derbyshire spar and blue John. It is of various colours, and beats an excellent polish: hence it is used in making ornamental vases, &c. Where there are flaws or cracks in the mineral, I am told the workmen have an ingenious method of filling them up with lead ore, which they execute so well, that it cannot be discovered but by very close examination. Such specimens of the mineral as are not fit for ornamental work, will answer very well for the production of fluoric acid. The refuse of these mines is, I understand, collected in Derbyshire, and used as a flux in the reduction of certain metallic ores.

According to some modern experiments, it appears that fluoric acid forms a part of the human teeth. It may be conjectured that this was a contrivance of Nature, to give more durability to these important organs than they would have had by phosphate of lime only.

Fluate of lime is very abundant in nature. It is often found in beautiful octahedral or cubical crystals. The other fluates are factitious salts, except fluate of alumine, which has lately been found in Greenland, in a mineral called the *chrysolite of Greenland.* It contains also a large portion of soda.

† Fluate of ammonia is a very delicate test of lime. This was first recommended by Scheele.

‡ It is from the property which these salts possess of fusing mineral substances and metallic oxides, that they are used by

of the borates, especially that of soda, d, by the strong acids, scaly crystals of bo- acid.

n you enumerate the boracic acids?

ıe principal are; the borates of lime,* of mag- ı,† and of potass; and the sub-borate of soda.‡

Vhat is the distinguishing characteristic of the NIATES?

hen heated with charcoal they are decom- d, and arsenic sublimes. This is known by lliaceous or garlic-like smell.

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ers, tin-men, &c. We employ sub-borate of soda to fuse stones as cannot be brought into fusion by the alkalies. In sing stones and minerals, the great art is to bring them into on. When this is effected, their component parts may be y separated by the different chemical re-agents. Mr. Che-

Which are the chief salts formed with arsenic acid?

The arseniates of lime, of barytes, of magnesia, of potass,* of soda, and of ammonia.†

What are the characters of the TUNGSTATES *?*

The salts called tungstates are combinations of the yellow acid of tungsten with the alkalies and earths. Most of them have a metallic and caustic taste.‡

Which are the principal salts formed with the tungstic acid?

The tungstates of lime,§ of magnesia, of potass, of soda, and of ammonia.

What are the generic characteristics of the ACETATES *?*

The acetates are all very soluble in water; are decomposed by the action of heat; and afford acetic acid when distilled with sulphuric acid.

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* Arseniate of potass may be formed by detonating in a crucible a mixture of nitrate of potass and arsenious acid.

This salt when heated melts into a white glass.

Scheele discovered that whenever tin is dissolved in arsenic acid, hydrogen gas is evolved, holding a portion of arsenic in solution. If ignited at the end of a metallic tube, this gas burns with a peculiar kind of lambent white flame.

† Most of the arseniates are formed artificially; few of them are used in the arts. They were first formed by Macquer. Fourcroy is of opinion that the nature of these salts ought to be further investigated. He imagines that the arsenic acid, in some of its combinations, will at some future day become of great utility in manufactures. Will not their expense be a bar to their introduction? not to mention the poisonous nature of every salt formed with this acid.

‡ We owe to Scheele the discovery of the salts of tungsten. They have lately been described with great accuracy by Vauquelin, in Journal des Mines, No. 19.

§ Tungstate of lime, which is found native, is well known to mineralogists: the other tungstates are formed by art.

some of the borates, especially that of soda, afford, by the strong acids, scaly crystals of boracic acid.

Can you enumerate the boracic acids?

The principal are; the borates of lime,* of magnesia,† and of potass; and the sub-borate of soda.‡

What is the distinguishing characteristic of the ARSENIATES?

When heated with charcoal they are decomposed, and arsenic sublimes. This is known by its alliaceous or garlic-like smell.

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braziers, tin-men, &c. We employ sub-borate of soda to fuse such stones as cannot be brought into fusion by the alkalies. In analysing stones and minerals, the great art is to bring them into solution. When this is effected, their component parts may be readily separated by the different chemical re-agents. Mr. Chenevix was unable to liquefy corundum by any means, till he made use of borate of soda.

* What is called cubic quartz is a borate of lime and magnesia.

† Borate of magnesia has also been found near Lunenburgh. The other borates are factitious salts.

‡ This salt, which is the common borax of commerce, is called sub-borate, because it contains an excess of soda. According to Bergman, it requires half its weight of boracic acid to bring it to the state of a neutral salt. Borax is generally brought from the East Indies in a state of impurity. The article is then called *tincal*. It has also been found near Lunenburgh, in the duchy of Brunswick, in a mountain of gypsum.

Borax is likewise found at the bottom of pools of stagnant water, in the kingdom of Thibet. A particular account of the management of the natives in procuring it may be seen in Dr. Anderson's Bee, vol. xvii. 22.

Boracic acid is found dissolved in several lakes of Tuscany. In the waters of the lake Cherchiago, near Montverdondo, in the province of Sienna, this acid exists in sufficient abundance to be advantageously converted into borax, by soda. Paloroni, a chemist of eminence in Florence, asserts that this acid is a modification of the muriatic, and that it may be totally formed by means of the latter acid.

What are the generic characteristics of the TARTRATES?

When the tartrates are exposed to a red heat, the acid is decomposed, and the base remains. The earthy tartrates are less soluble than the alkaline, but all are capable of combining with another base, and forming triple salts.

Can you enumerate the principal tartaric salts?

The principal are the tartrates of lime,* of strontian, and of potass; and the tartrates of potass, and soda, and of potass and ammonia.

What are the generic characteristics of the CITRATES?

The citrates are decomposed by the strong mineral acids; they yield traces of acetic acid

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sence of this earth, except it be supersaturated with muriatic or nitric acid—in either case it is necessary to take up the excess of acid by the addition of caustic ammonia before using the test.

Oxalate of potass is sometimes prepared in England, but it is found ready formed in the juice of *wood-sorrel*, in the state of a superoxalate. The other oxalates are not yet in use.

* Tartrate of lime is found in the tartar of commerce; and it is also formed by art, by adding lime or its carbonate to a boiling solution of cream of tartar. This latter salt is merely the common tartar, or argol, purified, which adheres to the inside of wine casks, and is brought in large quantities from the wine countries. There is a considerable demand for it by the dyers and other manufacturers; and both in the crude and refined state there is an excess of acid, therefore they are properly called *super*-tartrates of potass. Tartrate of potass and soda is what is usually called Rochelle salt, or sel de Seignette: it is formed artificially by adding soda in crystals to a solution of cream of tartar, till the excess of acid is saturated. A neutral tartrate of potass is also formed in our laboratories, called soluble tartar. The other tartrates are made without any view to their use in the arts.

when distilled: and the oxalic and tartaric acids decompose them.

Which are the principal citrates?

The citrates of lime, of barytes, of potass,* of soda, and of ammonia.†

What are the generic characteristics of the CAMPHORATES?

The camph[illegible] generally a bitterish taste; th[illegible]le by heat, and burn with a b[illegible]e.

Which are the [illegible]nphorates?

The camphor[illegible] of [illegible]e, of potass, of soda, of barytes, of ammonia, of alumine, and of magnesia.‡

What are the general characters of the SUBERATES?

The several suberates differ so much in their properties, that it would be difficult to characterize the genus otherwise than by saying that

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*The citrates are all formed artificially. Citrate of potass is used much in medicine, and is usually called the *saline draught*. The other citrates are not yet found to be of any use.

†The affinities of the citric acid are in the following order: barytes, lime, potass, soda, strontian, magnesia, ammonia, and alumine.

‡Camphoric acid saturated with potass forms crystals in regular hexagons; with soda, irregular crystals; with ammonia it forms needle-formed crystals; and with magnesia, a white pulverulent salt.

These salts, which have not been applied to any useful purpose, are also all formed artificially. For an account of their properties, consult Fourcroy's, or Thomson's System of Chemistry.

they generally possess a bitter taste, and are decomposable by heat.

Which are the principal suberates?

Suberates of barytes, of potass, of lime, and of ammonia.*

What are the generic characters of the PRUSSIATES*?*

The prussiates are so variable in their characters, and so easily altered, that little attention has been paid to their real nature. In the alkaline prussiates the acid is united so feebly as not to destroy their alkaline properties. The triple prussiates are those most known, and most useful.

Which are the principal prussiates?

The prussiates of potass and of lime, and the triple prussiates of potass, soda, lime, or ammonia, with iron: that of potass was formerly called prussian alkali.†

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How are these different salts known from each other?

They are known by the peculiar figure of their

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* The suberates, which are all factitious, are more or less soluble: some readily crystallize, others with difficulty; there are some which remain pulverulent, whilst others are deliquescent. The mineral acids decompose these salts, and precipitate from their solutions the suberic acid, which separates in the crystallized form. None of these salts are yet come into any use.

† The prussiates are all made by art, but the class is very interesting. There are four different prussiates of iron, which differ from each other in consequence of the different degrees

in six-sided prisms.

How is the crystallization of s

When a certain portion of

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of oxidizement of the iron. Prussiate
prussiate of potass and iron, is used a
presence of metals held in solution.
name of *prussian alkali*, is the best co
acid for detecting the existence of ir
importance to us as a re-agent, from
insoluble compounds with metallic ox
it occasions precipitates in metallic
colour according to the kind of met
best method of preparing this test,
vol. ii. 515.

* The chief work on this subject i
Abbé Haüy, to which I refer the
Notes, No. 15.

† When, either by the diminution
quid, or the reduction of the temperat
causes a separation of a portion of th
almost all cases the parts which are
arrangement, owing to the relation bet
ciprocal affinity. Hence those crystal
such variety, and which are produced

tion is evaporated, and the remainder left in a proper temperature at rest, the salts will shoot into crystals,* and will be found dispersed through the mother water at the bottom and at the sides of the vessel, and sometimes also on the surface of the solution.

What is meant by mother water?

Mother water is the liquor which remains after

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one of which is necessary to keep the parts of the substance in a state of minute division. In order that regular crystallization may take place, it is necessary that the fluid, whether water or caloric, or both, should be subtracted *gradually*. This gives an opportunity for the parts of the substance to unite regularly, according to their several attractions, and to produce regular crystals, such as Nature furnishes; whereas, a sudden subtraction of the fluid causes the particles often to unite in a shapeless mass.

Sir Isaac Newton seems to have had a very clear idea of the cause of crystallization. "When," says he, "a liquor saturated with a salt is evaporated to a pellicle, and sufficiently cooled, the salt falls in regular crystals. Before being collected, the saline particles floated in the liquor, equally distant from each other; they acted therefore mutually on each other, with a force which was equal at equal distances, and unequal at unequal distances: so, in virtue of this force, they must arrange themselves in an uniform manner."—Optics, book iii.

* The free access of air has considerable influence on this process. For if a saturated solution of any salt be put into a vessel boiling hot, and then excluded from the air, it will cool without crystallizing; but if the air be afterwards admitted, it will crystallize immediately. See Experiments, No. 17.

† In large laboratories the salts of commerce are prepared by evaporation and cooling, but it is necessary to vary the process for almost every different kind of salt. So much nicety is necessary, that many manufacturers are much perplexed by this part of their business, till they have established each process on the basis of experiment.

Some valuable directions for crystallizing salts may be found in Dr. Campbell's paper, in Nicholson's Journal, 8vo, vol. ii. 117. See also Le Blanc's directions in the same work, vol. i. 191; also the Encyclopædia Britannica, vol. iv. 443.

a salt has combined with its portion of water necessary for crystallization. By repeating the evaporation, and cooling,* mother waters generally afford fresh portions of salt.

What is the cause of the crystallization of salts?

The crystallization of salts is owing to their forming a chemical combination with a portion of the water in which they are dissolved;† in which combination the water parts with its caloric of fluidity and takes a solid form.

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* For boiling down saline liquors in the large way, leaden boilers, or boilers made with plates of sheet iron riveted together, are the most proper. The plates should not, according to my experience, be more than nine or ten inches wide, made of the best tough *hammered* iron, three-eighths of an inch thick in the middle, and one-fourth of an inch thick at their edges. If made with plates wider or thinner, the bottom will warp, and soon become useless. Common rolled iron will be sufficient for the sides. These pans are manufactured best in Lancashire and Cheshire, where there is a great demand for them for the salt works. Boilers of *cast iron* would crack by the adhesion of the salt to them.

† It must not be imagined that all crystallization is owing to solution in water. Melted sulphur always crystallizes on cooling, which is the case with many substances that have endured a strong heat. Many of the metals crystallize in this way, particularly grain tin. Nothing can exemplify this kind of crystallization better than muriate of lead, commonly called patent yellow. It affords beautiful and regular crystals on cooling. See Additional Notes, No. 23. If glass be kept in a red heat for a long time and cooled gradually—instead of being the transparent body we generally see it—it will crystallize like metals. Starch is another instance of what may be called *dry* crystallization; and probably, in every instance, the phenomenon may be attributed to the loss of caloric, and consequent shrinking of the whole substance. Dr. Garnet accounts for the origin of basaltes in this way. (See his Tour in the Western Isles.) The Giant's Causeway, in the county of Antrim in Ireland, is a most stupendous natural curiosity of this kind. It is formed of perpendicular pillars of basaltes, which stand in contact with each other. The pillars are irregular

What is the water called which combines with salts during their crystallization?

It is called the water of crystallization,* for it is this that gives them the crystalline appearance.

What quantity of water do salts combine with during their crystallization?

The quantity of this water varies very much in different salts; for though some salts take up very little water, others combine with more than their own weight, which is the case with alum, carbonate of soda,† and some others.

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prisms of various forms, from three to nine sides; but they are principally hexagons. The appearance of the whole is as neat as it is magnificent. The columns at Fairhead are 250 feet high, arranged in the utmost regularity and order; and from the base to the level of the sea there is a precipitous declivity of at least 300 feet, making together a perpendicular height of 550 feet. For a further account of this most astonishing natural curiosity, I refer the reader to "The honourable Mrs. Murray's Companion to the Western Highlands of Scotland," and to Dr. Richardson's "Observations," in Nicholson's Journal, vol. v. 4to, 321. See also Additional Notes, No. 14.

Basalt is now used in the manufacture of glass bottles. When calcined and pulverized it imparts to mortar the property of hardening under water.

* This water *solidifies* as the salt crystallizes, and becomes itself a part of the salt. When abstracted from salts, it is found to be as pure as distilled water.

† Take a portion of sulphate of soda (Glauber's salt) and dry it over a common fire, which will reduce it to less than half its weight. Dissolve this dried salt in three times its weight of boiling water, set the liquor aside, and, when cold, beautiful crystals resembling the original crystals will be found in the liquor. By an attentive examination of the liquor, the crystals may be seen to form as the liquor cools. This is a cheap and easy experiment, and may be exhibited to the pupil as an example of crystallization in general.

The property of crystallization seems to be a peculiar mark by which the salts may be distinguished from other bodies. Thus, it was formerly disputed whether carbonate of magnesia

Are salts as unalterable in their appearances as they are in their chemical properties?

No: *crystallized* salts are liable to changes in their appearance by exposure to atmospheric air.* Thus some salts deliquesce, and others effloresce, so as to lose their crystalline form entirely by such exposure.

What is meant by the DELIQUESCENCE *of a salt?*

Some salts have so great an affinity for water, that they absorb it with avidity from the atmosphere. Such salts thereby become moist or liquid, and are said to deliquesce, by exposure to atmospheric air.†

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should be called a salt; but when this combination was exhibited in a crystallized state, its saline character was readily admitted.

* A Table of the Action of Atmospheric Air on Salts.

Potass	Deliquesces	Nitrate of potass	None
Soda	Sub-deliquesces	—— soda	Sub-deliquesces
Carbonate of potass	If in crystals, none	—— ammonia	Agglutinates
—— soda	Effloresces	—— barytes	Slightly efflorescent
—— ammonia	None	—— lime	Deliquesces
—— lime	None	—— magnesia	Deliquesces
—— magnesia	None	Muriate of potass	None
Sulphate of potass	None	—— soda	None
—— soda	Effloresces	—— lime	Deliquesces
—— lime	None	—— ammonia	Sub-deliquesces
—— ammonia	Sub-deliquesces	—— barytes	None
—— magnesia	Effloresces	—— magnesia	Deliquesces

† Some deliquescent salts have so little force of cohesion, that the action of water, however small the quantity, is sufficient to prevent their crystallization; but even such salts may be crystallized by the addition of alcohol, for which the water

What is meant by the EFFLORESCENCE *of a salt?*

Some salts, having less affinity for water than atmospheric air* has, lose their water of crystallization by exposure, and readily fall into powder; such salts are said to effloresce. Carbonate and sulphate of soda are good examples of this property.

Are salts capable of any other changes besides efflorescence and deliquescence?

Yes: salts have the properties of solubility† and fusibility.

What is meant by the SOLUBILITY *of a salt?*

It is their capacity to unite with, and remain suspended in water; but the different salts possess

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has a greater affinity than it has for the salts. Therefore, whenever alcohol is added to such saline solutions, part of the water combines with the alcohol, and crystallization takes place. This shows that these salts do possess in themselves an active cohesion of parts.

* Muriate of barytes, *pure* muriate of soda, and some other salts, seem to have exactly the same affinity for water that atmospheric air has. Such salts neither effloresce nor deliquesce by any exposure to the atmosphere.

† Table of the Comparative Solubility of some of the Common Salts.

SALTS.	Solubility in 100 parts of water. at 60°.	at 212°.	SALTS.	Solubility in 100 parts of water. at 60°.	at 212°.
Sulphate of potass	6.25	20.	Muriate of potass	33.	
——— soda	37.	133.	——— soda	35.42	36.16
——— lime	0.22	0.2	——— barytes	200.	
——— ammonia	50.	100.	——— ammonia	33.	
——— magnesia	100.	133.	Carbonate of potass	25.	83.33
Nitrate of potass	14.25	100	——— soda	50.	100.
——— soda	33.	100	——— ammonia	50.	100.

different degrees of solubility,* requiring more or less of this fluid for their solution.

What is meant by the FUSIBILITY *of a salt?*

Salts have not only the property of dissolving in water, but will melt by exposure to great heat. The different salts require different degrees of heat to put them in a state of fusion.†

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* We generally denominate all salts as insoluble, which require for solution more than 1000 times their weight of water. The most general rule for judging of the *solubility* of a salt is by its taste. Those salts which have the most taste are generally the most soluble in water.

This difference in the solubility of salts is of great use in separating them from each other. The refiners of saltpetre operate entirely on this principle; for the rough petre, as it is called, is always contaminated with a portion of muriate of soda and other salts. In order to separate them they dissolve the whole in water, and then, by boiling the solution to evaporate a part of the water, the muriate of soda, &c. falls down, while the saltpetre is held in solution. When the greatest part of these salts is thus separated, the remaining liquor is suffered to cool, and the nitrate of potass is obtained in crystals. See Additional Notes, No. 22.

Most salts dissolve more copiously in hot than in cold water. Muriate of soda is almost the only exception to this general law. Was this deviation of Nature contrived in reference to the waters of the ocean?

† Tables of the fusibility of different salts have not yet been formed; but with the aid of Wedgwood's pyrometer it would be no very difficult task to ascertain the degree of fusibility of each. The relative fusibility of several of them is already known: for instance, it has been ascertained that sulphate of potass requires a much more intense heat to put it in a state of fusion than sulphate of soda; whereas nitrate and muriate of soda melt as soon as they become red. Some salts acquire fusibility by the loss of a part of their acid. Thus caustic alkalies are incomparably more fusible than carbonate of potass, or soda. In decomposing sulphuric salts in the large way, I have often hastened the process by the addition of a few shovels full of quick lime; but whenever this is had recourse to, the utmost caution is necessary in the management of the fire; as the alkali becomes, by this means, more liable to vaporization.

Have the different salts any action upon each other?

Yes: we have many instances of salts mutually decomposing each other.

What takes place in these decompositions?

When such salts are mixed in solution, the acid of the *first*, having more affinity for the base of the *second* than for its own base, unites itself to it, while the acid of the second combines with the base of the first: so that two new salts are produced, differing in appearance, and possessing properties different from those of the original salts.

What is the cause of this effect?

It is occasioned by chemical attraction, and the operation itself is called double decomposition, or the effect of compound affinities.*

What use is made of these decompositions?

By these means many valuable salts are procured for the use of the chemist and the manufacturer, which can be formed in no other way.†

What knowledge have we attained respecting the native *salts?*

Many of the salts are found native; and since

* Those who wish to investigate this subject may consult Bergman's treatise on "Elective Attractions," or Fourcroy's last System of Chemical Knowledge. See Nicholson's Translation of the latter work, vol. iv. 173.

† The following are some of those useful salts which are not found native, but are formed entirely by art:—sulphate of ammonia, nitrate and muriate of barytes, nitrate of ammonia, oxymuriate of potass, phosphate of soda, phosphate of ammonia, &c.

What native MURIATIC *salts are there?*

Muriate of lime and muriate of magnesia are found in abundance in sea-water;* muriate of ammonia appears in the neighbourhood of volcanoes; and muriate of soda not only exists in immense quantities in the ocean,† but vast moun-

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and when dry is a smooth and durable flooring. The whole expense is generally less than 1*s.* 6*d.* per square yard. Gypsum is also found in most of the cliffs of the Severn, especially at the Old Passage near Bristol. For the London market, perhaps, it might be gotten cheapest from the Isle of Sheppy, where it may be had in abundance.

* The magnesia of commerce is generally procured from this source. It is prepared in great quantities in the island of Guernsey, and elsewhere.

† In the south of France large trenches are cut near the sea, which fill with sea-water at high tide; the water being confined there by flood-gates, the sun evaporates it and leaves the salt in the trenches, from whence it is laid up to dry for use. Nicholas has published a long memoir on this manufacture of salt, in Ann. de Chimie, tom. xx. 78—188.

Dr. Shaw gives an account of salt-works on the coast of Syria, where the rocks on the sea-shore have been hollowed into salt-pans two or three yards long. By continually throwing in sea-water, as the aqueous part evaporates, a large quantity of salt gradually forms at the bottom. Travels in Barbary, last edition, page 344.

The ocean contains from $\frac{1}{77}$th to about $\frac{1}{77}$th of its weight of muriate of soda. On account of the cheapness of fuel at Newcastle, salt is procured there by the evaporation of sea-water. They evaporate 30 or 40 tons of water to procure one ton of salt.

At some places in Cheshire, they draw the brine from the salt-pits and saturate it with rock salt previous to its being boiled down. The port of Liverpool is supplied from these works, where it is sold, free of duty, for 1*s.* per cwt. for exportation. According to lord Dundonald, 100 tons of saturated solution of rock salt in sea-water contain 23 tons of salt.

In Sweden they freeze the sea-water, throw away the ice, and boil down the remainder to salt.

In the landgravate of Thuringia in Saxony a new method has been adopted in the manufacture of salt. A number of vessels of wood are placed firm upon posts six feet from the

tains in different parts of the world are entirely formed of this salt.*

Which of the NITRIC *salts are found native?*

Nitrate of potass is collected in various parts of the globe; nitrate of magnesia sometimes occurs in combination with that salt; and nitrate of lime† is found also in the same combination, and likewise in calcareous stones, and in mineral springs:—these are the only nitric salts that have been seen native in any large quantities.

Are any other of the salts found native?

Yes; vast rocks in Derbyshire and elsewhere

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ground, which may be covered or uncovered in an instant by a moveable roof, accordingly as the weather is dry or rainy. In this manner salt is obtained by the mere heat of the sun, and such salt is much purer than that which is procured by evaporation in boilers. Nicholson's Journal, 4to, vol. ii. 72.

* The salt-mines near Cracow in Poland, which have been worked ever since the middle of the thirteenth century, contain an immense store of muriate of soda. The excavations have been made with so much regularity and beauty, that these mines are visited by travellers as one of the greatest curiosities in the world. Eight hundred workmen are employed in them, who raise 168,000 quintals of salt annually. Through the enormous mass of salt, which presents to the eye no interruption in its saline texture, and at the depth of 450 feet, flows a stream of pure, fresh, and transparent water, which is received in large wooden vessels, where the workmen and horses of these subterranean regions quench their thirst. As it was impossible that this spring could filter through the salt, Nature, who buries her masterpieces in the bowels of the deepest mountains, has placed in this monstrous mass a stratum of clay sufficiently thick to allow the stream of water, destined to refresh the workmen, to pass through it in such a manner as to be protected from the action of the salt, of which a very small quantity would injure its salubrity. See an interesting account of these mines in vol. x. of the Phil. Mag.

† Some of the saltpetre grounds are now much more productive than formerly, owing to a knowledge of the circum-

ed to the will of the Creator, who has seen the composition of many of the mountainous of the globe, to prefer these compound sub- es to the more simple and inert earths.

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pear to have been designed for the successive production ial depositions, the renovation of soils, &c.—the rocks ite, the pillars of the globe, are so extremely hard, that nagined they would resist the constant washing of the for ages without any apparent diminution. Where they riginally fixed by the hand of Nature—

"they still remain,
Amid the flux of many thousand years,
That oft has swept the toiling race of men,
And all their labour'd monuments, away."—THOMSON.

is arrangement we perceive nothing like a fortuitous con- of atoms, but, on the contrary, the same satisfactory marks rivance, which obtrude themselves upon us whenever ly the phenomena of the world, or behold any of the

CHAPTER IX.

OF SIMPLE COMBUSTIBLES.

WHAT is a SIMPLE *substance?*

Those bodies* which have never yet been decomposed, nor formed by art, are called simple substances.

How many simple substances are there?

Very lately the simple substances were said to amount to about 50† in number; but since the truly interesting and very important discoveries of Sir Humphry Davy, it is scarcely possible to say what substances are not compound bodies.

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*The most minute particles into which any substance can be divided *similar* to each other, and to the substance of which they are parts, are termed the *integrant* particles: thus the smallest atom of powdered marble is still marble; but if the lime, the carbon, the oxygen, and the hydrogen of this marble be separated, we shall then have the *elementary* or constituent particles.

Suppose a little common salt were reduced to powder, even though it be ground as fine as could be effected by art, still every single particle, however minute, would consist of a particle of soda and a particle of muriatic acid; common salt being a *compound* body incapable of decomposition by mechanical means. But if we take a piece of sulphur, and pulverize that in the same way, every particle will be a homogeneous body, sulphur being one of the *simple* substances.

† If these substances were all capable of combining, the compounds formed by them would amount to many thousands; but several of them cannot be united by any means we know of.

Can you enumerate what are now deemed simple substances?

All the simple substances that we are acquainted with are, light, caloric, oxygen, the metals, some of the earths, and the simple combustibles, carbon and hydrogen.*

Is it well ascertained that these are all simple substances?

It is extremely probable that some of these bodies may be compound; but as no mode has yet been discovered of decompounding any of them, it will be more conducive to science, to consider them, for the present, as simple undecomposable bodies.*

Having already examined the nature of all these

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* If we omit the earths and alkalies (and there is abundant reason to believe that these are compound bodies) most of the simple substances are combustible, or bear some relation to combustion, either as products or supporters of combustion. *Light* and caloric are evolved during combustion: oxygen is the principle agent of combustion: and hydrogen, nitrogen, sulphur, phosphorus, carbon, and the metals, are the subjects, or the true instruments of this process.

† It is curious that most of those substances which were thought by the old chemists to be the elements of all other bodies, are found by our improved methods of experiment to be more or less compounded: while, of those which were formerly ranked among the class of compounds, there are a great number that are really not decomposable, and can only be placed among the simple bodies. *Air*, *fire*, *water*, and *earth* were by the ancients called the elements of the globe: modern chemistry has demonstrated, that the three last of these are really compound bodies; and there is reason to believe that the earths are also compound. On the other hand, *sulphur*, *phosphorus*, *carbon*, and the *metals*, which we call simple substances, were supposed formerly to be compounds.

Oxymuriatic acid has lately been added to the list of simple substances. See page 182.

substances, except the combustibles, we shall now enter upon the consideration of that class of bodies.—Endeavour, therefore, to enumerate the simple COMBUSTIBLES.

Besides the metals* there are four simple combustibles, viz. hydrogen, sulphur, phosphorus, and carbon.

Why are these substances called SIMPLE *combustibles?*

They are called *simple* because we have no proof that they are compounded: whereas oil, spirit of wine, wax, tallow, and other combustible bodies, are well known to consist of two ingredients at the least.†

It will be necessary to examine each of these substances separately:—therefore, what is the nature of HYDROGEN?‡

Hydrogen is the basis of what has been generally called inflammable air,§ and is one of the

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* The metals ought to have been included in this chapter, with the other simple combustibles; but as several of their properties are so very different from the four substances now described, it was thought most advisable to treat of them separately.

† For the nature of the compound combustibles, consult the chapter on Combustion.

‡ Mr. Cavendish was the first person who examined hydrogen gas and pointed out its nature. This was in the year 1766. Dr. Black then suggested the propriety of applying it to the inflation of air balloons; and Mr. Cavallo was the first who put it in practice. This gas is about twelve times lighter than atmospheric air.

§ Like all other combustibles, hydrogen will not burn unless in contact with atmospheric air, or some substance that contains oxygen. If a portion of atmospheric air be mixed with this gas, and fire be applied, it will explode with violence. It is related of Pilatre de Rozier, that, having mixed one part of common

component parts of water;* but it cannot be exhibited in a separate state. We therefore know

with nine parts of hydrogen gas, and drawn the mixture into his lungs, it caught fire by accident as he respired it, and the whole of the gas exploded in his mouth and nearly deprived him of life. The shock was so violent, that at first he thought the whole of his teeth had been driven out, but fortunately he received no lasting injury whatever. Being myself engaged some years ago in a process in which a large quantity of hydrogen gas was evolved, and having incautiously brought a lighted candle too near the apparatus, the whole exploded with a tremendous crash; and several 12-gallon glass receivers were shattered into ten thousand pieces, and driven in all directions about the laboratory. Such accidents should be noticed in every elementary chemical work, in order to inspire the young pupil with caution when operating on such substances.

* Hydrogen is the most inflammable substance we are acquainted with; that is, it combines with more oxygen than any other body, and occasions more heat by its combustion. It may be remarked that OXYGEN is *mild* when in the proportion of 22 per cent. in atmospheric air, and highly *corrosive* in the proportion of 70 per cent. in nitric acid; or even in that of 40 per cent. in sulphuric acid:—How is it then, that it is found in the ratio of 85 per cent. in water, and that this compound, compared with the others, should be perfectly mild and *innocent*? Instances of a similar accommodation of the elementary substances have been adduced; and though we cannot comprehend the nature of their operation, we can perceive that the ultimate end of the Creator is our convenience and happiness. See pages 60, 61, and 185. Most oxidized substances, when taken internally, act perceptibly on the system; yet water, the most oxidized of all others, has comparatively little influence, because its oxygen is so forcibly retained by the hydrogen. Had the affinity of hydrogen for oxygen been as feeble as that of nitrogen and oxygen, what is now the most salubrious beverage would have operated as a corrosive poison.

Berthollet has shown that at all temperatures there is a greater disposition in hydrogen than in carbon to combine with oxygen. Chemical Statics, vol. i. 244.

Oil, tallow, wax, &c. used for producing light, do all acquire their power of burning *with flame*, from the hydrogen, which is a component part of all these substances.

A mixture of oxygen and hydrogen gases produces the most powerful heat yet known. This may be shown by preparing a bladder full of each of these airs, and forcing some out of each into a common tube connected with both, and *throwing a stream* of the mixed gases on burning charcoal,

it only in combination with other substances, or in the gaseous form, that is, with caloric.*

In what other compounds is hydrogen an ingredient?

Hydrogen gas may be combined with water, sulphur, phosphorus, or with carbon.

What is the nature of the compound of hydrogen and water?

Water may be made, by pressure, to absorb a considerable portion of hydrogen gas. It is called hydrogenated water, and is said to be useful in medicine.†

What is the nature of the compound of hydrogen and sulphur?

Sulphur dissolved in this gas forms sulphuretted hydrogen gas,‡ which is a very fetid elastic

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or on any other substance in the act of combustion. These bladders should each be furnished with a small metallic pipe and stop-cock, and the tube connecting with both should have a very small orifice, in order that a regular stream of the commixed gas may be thrown upon the burning substance. *In performing this experiment all solid vessels should be discarded, for fear of an accident by explosion. When bladders are used no damage can arise, even if such an accident should happen.*

* From some late experiments there is reason to suspect that hydrogen gas may be a metal in the aerial form. See Philos. Trans. for 1808.

† Hydrogen gas is slightly absorbable by water, but by *pressure* water may be made to absorb near a third of its bulk of it. It is said that water, thus impregnated, is useful in inflammatory fevers and other complaints which require similar treatment.

‡ To obtain sulphuretted hydrogen gas, melt together in a crucible three parts by weight of iron filings and one of sulphur; reduce the mass to powder, and put it with a little water into a glass vessel with two mouths: fix one end of a crooked glass tube into one of these mouths, and let the extremity of the tube pass under a glass jar in a pneumatic trough, the jar

somewhat heavier than atmospheric air and
e in water.

at are the properties of sulphuretted hydrogen

phuretted hydrogen gas* possesses all
haracters of an acid:† it combines with

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nverted and full of water. Then pour diluted muriatic
rough the other mouth of the vessel, which must imme-
be closed up. Sulphuretted hydrogen gas will now be
ged in abundance and flow into the glass jar, displacing
er.

gas is composed of 15 parts of sulphur and 1 of hydrogen.
ific gravity, compared with hydrogen, is 16 to 1. 100
inches of it weigh between 36 and 37 grains. Davy's
Phil. vol. i. page 231.

r impregnated with sulphuretted hydrogen gas is of use to

earths, alkalies, and with several of the metallic oxides; and forms with them those substances called *hydrosulphurets*.

What are the properties of the hydrosulphurets?

The hydrosulphurets are soluble in water, and their solutions precipitate the metallic oxides from metallic solutions. Exposure to the air, however, decomposes these hydrosulphurets when dissolved in water.†

What is the nature of the combination of hydrogen and phosphorus?

Hydrogen gas when combined with phosphorus

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the doctrine of Lavoisier, who asserted that oxygen was the only principle of acidity. Muriatic acid also has not yet been proved to contain oxygen.

Sulphuretted hydrogen is capable of combining with an additional portion of sulphur, forming a compound which may be called supersulphuretted hydrogen. For its properties see Murray's Chemistry, vol. ii. 451.

We have a mineral called swinestone, (or fetid carbonate of lime) which is so fully impregnated with this compound that, if it be merely rubbed, the disagreeable odour of sulphuretted hydrogen will be very perceptible.

† The waters of Harrowgate, Aix-la-Chapelle, and others of a similar nature, owe their medicinal properties to sulphuretted hydrogen gas and muriate of soda. The *salt of Harrowgate* of the Hindoos, which is almost the only article of Hindoo physic, and is sold in every village, is chiefly composed of muriate of soda and sulphuretted hydrogen. It is taken by these people for every complaint. The farriers give it to the horses, and seem to understand the principle on which it acts: for when they have given a dose to the animal they always give him water to extricate the gas. *Henderson on Hindoo Physic.*

Secret correspondence has often been carried on by means of Harrowgate water. A letter written with a solution of acetate of lead is illegible: but, if it be dipped in this water, the writing will appear, and shortly become almost black. Hydrogen has the property of reviving metallic oxides; hence ladies who have used metallic cosmetics, have become dark tawnies by bathing in these waters. See a note on Bismuth, chapter x.

forms *phosphuretted hydrogen gas.** This gas has a fetid putrid smell, and takes fire whenever it comes in contact with atmospheric air.†

What is the nature of the combination of hydrogen with carbon?

Carburetted hydrogen gas‡ is carbon dissolved

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* Phosphuretted hydrogen gas may be formed by boiling a little phosphorus in a solution of pure potass. The water is decomposed thereby, and furnishes the hydrogen. The retort should be nearly filled with the solution, otherwise the gas will inflame.

This gas may be formed by introducing phosphorus into a glass jar full of hydrogen gas standing over mercury, and melting the phosphorus by means of a burning glass. This compound gas burns with great rapidity in common air, but in oxygen gas the combustion is extremely brilliant. If bubbles of it be made to pass up through water, they explode in succession as they reach the surface of the liquid, and a beautiful coronet of white smoke is formed, which rises slowly to the ceiling of the room. This gas is one of the most combustible substances we know of. Thomson, vol. i. 66.

Sir Humphry Davy forms phosphuretted hydrogen gas by decomposing water with zinc and sulphuric acid, and adding to the mixture small pieces of phosphorus. But as some management is necessary in order to conduct the process successfully, I refer the reader to his paper in Nicholson's Journal for April 1802.

The facility with which phosphuretted hydrogen gas inflames, is no doubt owing to the phosphorus being so minutely divided by the hydrogen.

† If bits of phosphorus be kept for some hours in hydrogen gas, *phosphorized hydrogen* gas is produced, having somewhat of the smell of garlic. If bubbles of it are thrown up into oxygen gas, a brilliant blueish flame will immediately pervade the whole vessel. This slow combustion is owing to the gas containing *less* phosphorus than the *phosphuretted hydrogen* gas. It is this gas which is often seen hovering on the surface of burial-grounds, known by the name of *will-o-the-wisp*.

"On distant swampy heath I see
A will-o-wisp,——ah luckless he
Who to next hamlet bends his way!
That glimpse will lead him far astray."

‡ In hot weather this gas is formed at the bottom of stagnant waters, and may readily be collected at their surface, by

in hydrogen: this has likewise been called heavy inflammable air.*

-u-pending a bottle of water over the pool, similar to the decanting of gases over a pneumatic trough, and stirring up the mud to di engage the carburetted hydrogen.

This gas generally contains a portion of carbonic acid mixed with it. Both these aëriform fluids are produced by the decomposition of water by putrid animal and vegetable matter. Such decompositions take place chiefly when the sun shines upon these waters, caloric being necessary to all gaseous compounds.

Carburetted hydrogen may be formed artificially by exposing charcoal in glass vessels filled with hydrogen gas to the rays of the sun. It is invisible, elastic, and inflammable. The proportions of carbon and hydrogen vary according to the processes by which the gas is obtained. Its specific gravity, in its purest form, is to that of hydrogen gas as rather less than 8 to 1. One hundred cubical inches weigh about 17 grains.

* This gas is procured from pit-coal by dry distillation for the purpose of forming the thermo lamp, and is now proposed to be employed for lighting the public streets, light-houses on the sea-coasts, mines, manufactories, &c. See page 16. One pound of coal yields about 24 gallons of this inflammable gas, and the remainder serves for fuel; it being excellent coke. Its combustible property, and that it serves for the purposes of light and heat, were discovered about 70 years ago, by the Rev. Dr. John Clayton. See Mr. Hume's letter in Nicholson's Journal, vol. xvi. p. 170. For an account of its employment in the support of a popular superstition, see page 168. See also Additional Notes, No. 66.

All oils, resins, gums, wax, sugar, and numberless other inflammable substances, are composed of hydrogen and carbon in various proportions, and, in many cases, with the addition of oxygen. Hydrogen is also one of the bases of all animal and vegetable acids: and with nitrogen it constitutes ammonia.

When a mixture of four parts of oil of vitriol and one of alcohol is heated in a retort, a gas is generated which is found to be a compound of carbon and hydrogen, called *super carburetted hydrogen* and also *olefiant gas*. When kindled it burns with a beautiful white flame of intense splendour. According to Sir Humphry Davy, the specific gravity of this gas is to that of hydrogen nearly as 18 to 1. One hundred cubical inches of it weigh between 29 and 30 grains. When olefiant gas is mixed with an equal volume of chlorine, the two gases condense each other, and a peculiar fluid is formed, which has been supposed to be an oil.

What is the origin of SULPHUR?

Sulphur is found in most parts of the world* combined with metals, from which it is procured by roasting; it also flows from volcanoes; it is sublimed from the sulphureous grounds in Italy, and is found in many mineral waters,† combined with hydrogen.

What is the nature of sulphur?

Sulphur, or brimstone as it is sometimes called, is a solid, opaque, combustible‡ substance, of a pale yellow colour, insoluble in water, very brittle, and with little taste or smell. Its specific gravity

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*Sulphur is so plentifully diffused, that probably it was known very early: according to Pliny, it was used in his time in medicine, and for bleaching wool.

Sulphur is procured in large quantities from martial pyrites and other metallic ores. It is also found in abundance in the state of native sulphur, as it is called, near several volcanoes, in different parts of the world. According to Dr. Anderson, there are mines of it in the kingdom of Thibet. *The Bee*, vol. xvii. 25. In the Isle of Anglesea it is sublimed from the copper ore, and collected in large chambers which are connected with the kilns by means of long horizontal flues. See Henkel's Pyritologia.

†Sulphur has been discovered in cresses, horseradish, and several other vegetables. It is also evolved from animal substances, during their putrefaction, in combination with hydrogen. The change which silver undergoes when immersed in an egg, shows the presence of sulphuretted hydrogen.

‡ Sulphur during its combustion combines with oxygen, and becomes an incombustible substance. Like phosphorus, it is eminently combustible, owing to its great affinity for oxygen. See page 176.

If sulphur be kept melted in an open vessel, it at length becomes thick, as has often been observed; but I believe it has not been noticed by any writer on chemistry, that it has the peculiar property of becoming *thinner* as it cools, till it is nearly as thin as water. This is an exception to the general law, by which caloric causes the particles of bodies to recede from each other.

is 1.990, or nearly twice as heavy as water. It has various uses in medicine and the arts.

What compounds are formed by means of sulphur?*

Sulphur is the base of several compounds; it unites with oxygen, hydrogen, nitrogen, phosphorus, the alkalies, the metals, and with some of the earths.†

What are the compounds of sulphur and oxygen?

If sulphur be kept in fusion in atmospheric air, it absorbs a small quantity of oxygen, and forms oxide of sulphur;‡ if it be heated sufficiently to take fire, it burns with a pale blue flame, and becomes converted to *sulphurous* acid; but if sulphur be burned in pure oxygen, it absorbs the full dose of this gas, and *sulphuric* acid is the product.§

What are the compounds of sulphur and the alkalies?

Sulphur will combine with potass, with soda,

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* "Nature employs sulphur in a great number of her operations; she presents it under many forms among fossils; charges with it the waters denominated sulphureous; mineralizes with it the metals; causes it to pass into the vegetable and animal fibres; and exhibits it to chemists in an infinite number of combinations."

† Sulphur is used in large quantities for making gunpowder. When exhibited as a medicine, it penetrates to the extremities of the most minute vessels, and impregnates all the secretions; as may be perceived by those who have taken it for any length of time. Sulphur has many uses in the arts, and has been employed with advantage in stopping the progress of fermentation in wines and other fermented liquors.

‡ See the chapter on Oxides; also Fourcroy's System of Chemical Knowledge, vol. i. 276.

§ For an account of the changes which take place in sulphur when it becomes oxygenized, see page 176.

and with ammonia; which compounds possess several curious and interesting properties.

What are the general characteristics of the akaline and earthy sulphurets?

They are hard substances of a brown colour, resembling the liver of animals; they absorb water from the atmosphere, and then emit a fetid odour, similar to that of putrid eggs. They have the property of decomposing water, and by that process become partially converted to alkaline or earthy sulphates.*

What knowledge have we acquired of the combinations of sulphur with the earths and metals?†

Sulphur may be combined artificially with most of the metals,‡ and with some earths: but many of the metallic sulphurets are found native in great abundance.

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* The sulphurets can only exist in a state of desiccation, or at least can contain but a very small portion of water without the water being decomposed, which occasions the sulphurets to be changed into hydroguretted sulphurets. The alkaline sulphurets have also the property of decomposing the metallic oxides.

† There have been instances, where people have taken frequent doses of mercurial medicine, of the human skin becoming suddenly quite black a few hours after the outward application of sulphur-ointment, to the great terror and amazement of the patient. This was occasioned by the mercury exuding through the pores of the skin to unite with the sulphur, in consequence of its affinity to that substance; and a true æthiops-mineral was formed over the whole body.

‡ Some of the metallic sulphurets have much colour, and are employed as pigments.

Sulphuret of lime is recommended by Mr. Higgins as a cheap substitute for potass in bleaching. For the method of preparing it, consult his work on the Theory and Practice of Bleaching, published in Ireland in 1799.

What is the origin of PHOSPHORUS?

Phosphorus is a peculiar substance, chiefly of animal* origin. It was formerly obtained by a very tedious and disgusting process; but is now generally procured by the decomposition of the phosphoric acid which is found in animal bones.†

What is the nature‡ of phosphorus?

Phosphorus is a solid inflammable§ substance.

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* The real origin of phosphorus is very obscure: some have supposed it to be a product of the process of animalization, and several curious facts might be adduced to strengthen this opinion.

† Phosphorus was accidentally discovered at Hamburg, in 1669, by an alchemist of the name of Brandt; and two years afterwards one Kraft brought a small piece of this substance to London, on purpose to show it to the king and queen of England. Mr. Boyle afterwards discovered the process, which he described in the Phil. Trans. for 1680. Mr. Boyle instructed Mr. Godfrey Hankwitz, of London, how to procure it from urine, so that he was the first who made it for sale in England; and he continued to supply all Europe with it for many years.

The writer of this has in his possession a scarce portrait, by Vertue, of this chemist in the midst of his laboratory surrounded by his chemical apparatus: the form of which shows that even at that time they had the means of accurate analysis, if they had had a rational theory to direct them. From a Latin inscription it appears that he had this print engraved to present to his customers on his taking leave of them, when about to enter upon his travels abroad to sell phosphorus.

The discovery of phosphorus proves that valuable discoveries may be made even by men who have no means of appreciating their nature. Stahl maintained that it was the *marine salt* contained in urine which yielded phosphorus.

‡ Phosphorus when taken internally is poisonous. It is related in the Annales de Chimie that a great number of domestic fowls and turkeys were poisoned, merely by drinking the water in which some newly made phosphorus had been washed. Though poisonous, it has been given in *small* quantities by some French physicians, in malignant fevers, to stop the progress of gangrene, in which it succeeded beyond all hope. Nicholson's Journal, vol. iii. 85.

§ If a piece of phosphorus be placed on the surface of water a little below the heat of boiling, it will immediately inflame. This

t is the nature of these compounds?

sphorus forms with oxygen, according to portion of the latter, either oxide of phos-, or phosphorous acid, except it be saturated xygen, and then phosphoric acid;* with gen, phosphuretted hydrogen;† with nitro- hosphuretted nitrogen; with sulphur, phos- of sulphur, and sulphur of phosphorus; with tals, metallic phosphurets;‡ and with some earths, earthy phosphurets.

t is the origin of CARBON?

carbon is known only in the diamond; nay be procured in the state of charcoal by g a piece of wood closely covered with sand, ucible.

acid;* with hydrogen and caloric, carburetted hydrogen gas;† with nitrogen and caloric, carburetted nitrogen gas; with sulphur, carburetted sulphur; with phosphorus, phosphuretted carbon; and with iron, plumbago, or carburet of iron.‡

Some of these compounds having been already examined, it will now be expedient to consider the other states and combinations of carbon;—therefore, what is charcoal?

Charcoal, which is the combination with which we are the most familiar, is the coaly residuum of any vegetable that has been burnt in close vessels.§

What are the characters and appearances of charcoal?

Charcoal is generally black, sonorous, and brittle; very light, and destitute of taste or smell.‖

What are the properties of charcoal?

Charcoal is a powerful antiseptic;¶ has great

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* See page 187. † See page 256. ‡ See page 278.

§ Charcoal for common purposes is made by a less expensive process. The wood is disposed in heaps regularly arranged, and covered with earth, so as to prevent the access of any more air than is absolutely necessary to support the fire, which is kept up till all the water and oil are driven off; after which the fire is extinguished by shutting up all the air-holes. A more economical method is first to collect the pyroligneous acid from the wood, by dry distillation in large iron cylinders; and then the residuum in the cylinders will be charcoal of the best quality. By this process, his majesty's gunpowder works have for some time past been supplied with charcoal.

‖ Charcoal is so porous that it may be seen through with a microscope; and, however large the piece, it may be readily blown through.

¶ "All sorts of glass vessels and other utensils may be purified from long retained smells of every kind, in the easiest and most perfect manner, by rinsing them out well with charcoal

affinity for oxygen;* is unalterable and indestructible by age;† and, if air and moisture be excluded, is not affected by the most intense heat.

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powder, after the grosser impurities have been scoured off with sand and potash. Rubbing the teeth and washing out the mouth with fine charcoal powder will render the teeth beautifully white, and the breath perfectly sweet, where an offensive breath has been owing to a scorbutic disposition of the gums. Putrid water is immediately deprived of its offensive smell by charcoal."—Crell's Journal, vol. ii. 170.

Meat, which is only a little tainted with putridity, may at once be made sweet by charcoal: and if common raw spirits be agitated with charcoal they will be deprived of their bad flavour. A gentleman in the spirit trade however informs me, that spirits treated this way are very apt to resume the old flavour, if kept in the cask only a few months.

* Charcoal, from its affinity with oxygen, will decompose the sulphuric and nitric acids. It decomposes the latter with great rapidity. If the charcoal be dry and finely powdered, and the acid strong, and allowed to run down the inner side of the vessel to mix with the charcoal, it will burn rapidly, giving out a beautiful flame, and throwing up the powder so as to resemble a brilliant fire work.

† "The beams of the theatre at Herculaneum were converted into charcoal by the lava which overflowed that city; and during the lapse of seventeen hundred years the charcoal has remained as entire as if it had been formed but yesterday, and it will probably continue so to the end of the world. The incorruptibility of charcoal was known in the most ancient times; the famous temple at Ephesus was built upon wooden piles, which had been charred on the outside to preserve them." Watson's Essays, vol. iii. 48.

"It is said that there still exists charcoal made of corn in the days of Cæsar, which is in so complete a state, that the wheat may be distinguished from the rye."—Willich.

"About forty years ago a quantity of oak stakes were found in the bed of the Thames, in the very spot where Tacitus says that the Britons fixed a vast number of such stakes, to prevent the passage of Julius Cæsar and his army. They were *charred* to a considerable depth, retained their form completely, and were firm at the heart." Dr. Robinson. The ancients wrote with levigated charcoal, the most indestructible

To what uses is charcoal applied?

In the preparation of gunpowder, charcoal is a most important ingredient; it is also employed in purifying rancid oils, for decomposing the sulphuric acid, and for many other purposes, by the chemist and the manufacturer.*

Is charcoal a simple or a compound substance?

Common charcoal is a compound substance; it is an *oxide* of carbon, or the woody fibre partially oxidized; it also contains hydrogen,† and a portion of fixed alkaline salt and earth, but these are rather adventitious than essential ingredients.‡

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substance we know; and accordingly, the writings found in Herculaneum are still a perfect black. Ib. vol. ii. 480.

Casks charred in the inside are now used to preserve water in sea voyages; and such casks are found to preserve the water uncorrupted. Dr. Black, vol. ii. 285.

* Charcoal is used by mathematical instrument-makers and engravers to polish their brass and copper plates. Plates of horn and lanthorn leaves are polished with it. It is also much used by artists in tracing the outlines of drawings. See Additional Notes, No. 2.

† Charcoal generally contains hydrogen, which it retains after the most powerful calcination. It is perhaps the want of hydrogen which renders the diamond much less combustible than charcoal. To the absence of oxygen this may in part be attributed, as plumbago and anthracolite, both oxides of the first degree, are less combustible than charcoal. For the same reason, manufacturers obtain higher degrees of heat with *coke* than with charcoal; for coke, being less oxidized than charcoal, requires a higher temperature for its combustion. To the attention of those manufacturers who reside near coal-works where the small coal is fit for making coke, I take this opportunity of recommending the coke ovens of the duke of Norfolk. See Additional Notes, No. 50. The small of some coal will not coke.

‡ Messrs. Allen and Pepys have lately determined by experiment that charcoal properly prepared contains no sensible quantity of hydrogen, but that it absorbs moisture if exposed to the air only a few hours, which renders the result of analysis uncertain.

What is carbon?

The base of common charcoal, divested of all impurities, is known to chemists by the name of CARBON.

What is the most striking property of pure carbon?

Carbon is capable of crystallization, though not by art, and in that state it is called *diamond.**

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* The diamond is the purest carbon we know of, but common charcoal contains only 64 parts diamond and 36 oxygen in every 100; carbonic acid has 28 parts charcoal and 72 of oxygen, or 18 diamond and 82 oxygen. The diamond is chiefly found in the kingdom of Golconda in Asia, and in Brazil. It always occurs crystallized; indeed, if not, it would be carbon and not diamond. See a note respecting the diamond under the article Steel, in the chapter on metals; where you have an additional proof that diamond is simple carbon. It is wonderful that Newton, who had no chemical means of examining the diamond, should have conceived the idea of its inflammable nature. See Additional Notes, No. 35.

Mr. Tennant has satisfactorily shown that *the diamond is* pure carbon, carbon crystallized. See *Phil. Trans.* for 1797. The diamond is the hardest substance in nature, and one of its rarest productions. From its hardness it is employed for sawing and boring the hardest stones. "Diamonds are usually found in an ochreous yellow earth, under rocks of grit stone; they are likewise found detached in torrents, which have carried them from their beds. They are seldom found above a certain size. The sovereigns of India reserve the largest, in order that the price of this article may not fall. Diamonds have no brilliancy when dug out of the earth, but are covered with an earthy crust."—Fourcroy. Diamonds are also found in considerable numbers in the island of Borneo. Whenever the mines are searched for them, an overseer attends, and watches the workmen with great care, that the largest may be secured for the sovereign prince. Notwithstanding, they are frequently conveyed away clandestinely by the workmen, who will swallow them. Von Wurmb's History of Borneo.

A minute account of the diamond mines of Brazil may be seen in Ann. de Chim. tom. xv. 32; and in Nicholson's Journal, 4to, vol. i. 24.

The usual method of calculating the value of diamonds, is

What other properties has carbon?

Carbon has the property of de-oxidizing the oxides of metals and other combustible substances,* and with this view it is often used in the arts. These purposes are effected by means of fire, the carbon uniting to the oxygen to form carbonic acid;† and the metal, thus deprived of oxygen, is left in its pure state.

Does carbon enter into any other combinations?

Carbon is found in large proportions in bitumen, petroleum, and pit-coal:‡ it seems to be

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by squaring the number of carats, and then multiplying the amount by the price of a single carat: thus, supposing one carat to be worth 2*l.* a diamond of 8 carats is worth 128*l.* being 8×8×2. A carat is 4 grains. *Polished* diamonds, without blemish, are worth about 6*l.* per carat.

In the year 1772, the empress of Russia purchased a diamond that weighed 779 carats, near 6½ ounces troy. She paid the immense sum of twelve tons of gold for it, and granted a pension of 4000 roubles per annum to the vendor.

* Charcoal has such a powerful affinity with oxygen, that in a proper degree of heat it will abstract it from all other substances.

† The merit of the discovery of carbonic acid is due to the illustrious Dr. Black of Edinburgh. Those who have not been in the habit of reading the early chemical writers can have no idea of the service which this great man has rendered the science by his very accurate investigation of this compound.

‡ There are good reasons for supposing that bitumens and pit-coal have been formed in the bed of the sea by the decomposition and deposition of animal matters. The quantity of volatile alkali which these substances yield on distillation favours this opinion. An interesting paper by Mr. Kirwan, on the proportions of carbon in the different kinds of coal, will be found in Nicholson's Journal, 4to. vol. i. 487.

See an ingenious paper by Mr. Hatchett, on the origin of bitumen, &c. in the Phil. Trans. for 1804. See Additional Notes, No. 39.

An interesting account of the springs of fossil tar near Shrewsbury, and at Colebrook Dale, may be seen in Archdeacon Plymley's View of the Agriculture of Shropshire.

ready formed also in vegetables; and enters into most animal and some mineral substances.*

What is the proportion of carbon in pit-coal?

Pit-coals vary in quality, according to the different proportions of carbon and bitumen which they contain;† but carbon is the *chief* ingredient in all. What are called *slaty* coals contain also from 10 to 40 per cent. of earth;‡ and some

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* Charcoal has the property of forming an intimate union with the fixed alkalies, if fused with them.

Plumbago contains a small quantity of oxygen: it is therefore diamond in its first state of oxidizement, or an oxide of the first degree; common charcoal, an oxide of the second; carbonic oxide, of the third; and carbonic acid, the product of the complete oxidizement of carbon.

† The immense quantity of pit-coal which is deposited beneath the surface of the earth is truly astonishing, and affords abundant matter for reflection. This kind of fuel is consuming day after day in incalculable quantities; and so great is the store, that there is no probability of its being exhausted for ages yet to come. Supposing the formation of pit-coal to be owing to the deposition of marine animal matter; the same process must be still going on, and the inmost recesses of the present seas may be receiving the materials of fuel for the inhabitants of new continents in the most remote periods of the world. The wise economy of the great Author of Nature, in this constant circulation of the elements of matter, is equalled by nothing but his own infinite beneficence:

> "Who, not content
> By one exertion of creative power
> His goodness to reveal; through every age,
> Through every moment up the tract of time
> Adjusts, accommodates, and blesses all."

On the formation of coal, consult Mr. Williams's "History of the Mineral Kingdom," and Parkinson's "Organic Remains."

‡ There are four species of coal, very distinct from each other: the *graphite* of Werner, or plumbago; the *anthracolite*; the *jet*, or cannel coal; and the common coal.

One hundred parts of plumbago contain 90 charcoal and 10 iron. The best quality, which is found at Keswick in Cumberland, is used in making pencils. Plumbago has also been found lately in considerable quantities in an estate about

coals contain a considerable quantity of *martial pyrites*, the sulphuret of iron.

What is the use of carbon in the vegetable kingdom?

Carbon is not only a component part, but forms nearly the whole of the solid basis of all vegetables, from the most delicate flower in the garden to the huge oak of the forest.*

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7 or 8 miles north of the town of Ayr in Scotland, and in some parts of that neighbourhood it even occurs at the surface of the ground.

Anthracolite, or coal blend, is distinguished from other coal by burning without flame. It is composed of 64 charcoal, 33 silex, and 3 parts of other earths.

Jet is composed of bitumen and charcoal: 75 parts charcoal, 22 parts bitumen, and 2 parts earth.

Common coal is composed of bitumen and charcoal in different proportions, according to its quality and the places whence it is procured. At Newcastle upon Tyne, martial pyrites are often found mixed with the coal, in such abundance as would render the coal unsaleable; but persons are employed to pick out these pyrites and remove them to a proper situation, where in process of time they become acidified, and fit for the production of green vitriol. See an account of this process under the article Salts of Iron. This species of coal, when in contact with water, is apt to be decomposed, and to burn spontaneously. Ships at sea have sometimes been suspected to have been lost by this means. His majesty's ship Ajax, of 74 guns, lately took fire in the middle of the night on a station in the Mediterranean, and no cause for that dreadful catastrophe has yet been assigned.

* It has been discovered that air which has been spoiled by the breathing of animals is peculiarly fitted for the vegetation of plants: no doubt this is owing to its containing a larger portion of carbonic acid.

By the analysis of soils it has been proved, that of all the substances found in the mixture of earths which constitute a soil, calcareous earth contributes most certainly to its fertilization. This probably proceeds from the carbonic acid. An interesting account of some experiments on manures, by Mr. Arthur Young, on a small scale, may be seen in the Retrospect, vol. I. 118.

If carbon forms so large a part of all vegetables, what occasions that infinite variety which we observe in the vegetable creation?

We are in a great measure strangers to the economy of vegetables: but much of this variety may be attributed to the different modifications of carbon,* as well as of [illegible] principles which enter into their const[illegible]

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* Vegetables have the power to absorb oxygen from the atmosphere, and to transmit it to the absorbent vessels of the roots. It cannot be questioned but that this oxygen becomes useful in vegetation, by converting the carbon of manures into carbonic acid. See Additional Notes, No. 48.

The operation of paring and burning turf, which is always found by farmers extremely serviceable to their lands, is doubtless rendered universally advantageous from the carbonaceous matter which is produced by the burning.

† When we consider the small number of simple substances which enter into the composition of plants, how astonishing is the variety that has been given us by the profusive hand of Nature! The species of vegetables already known are more than 40,000, and large additions are daily making to this number by new discoveries. Is it possible that so bountiful a provision can have been made by Nature ultimately for the use of man?—Yes: "for him she has covered the earth with plants; and though their species be infinite in number, there is not one but may be converted to his use. She has selected some out of every class to minister to his pleasures, or his support, wherever he shall please to fix his habitation. Others serve for his bed, for his roof, for his clothing, for the cure of his diseases, and for the fire of his hearth."—St. Pierre.

Fourcroy has remarked that "vegetables may be considered as beings intended by nature to *begin* the organization of crude matter, and to dispose the primitive materials of the earth and atmosphere in order to become the source of life, and consequently to establish a communication between minerals and animals; from whence it follows, that plants are truly chemical apparatus employed by nature to produce combinations which would not take place without them." Nature is as admirable in the simplicity of her means, as in the constancy and regularity of her operations.

What products of vegetation are there which are indebted to carbon for their formation?

Carbon not only constitutes the base of the woody fibre, but is a component part of sugar, and of all kinds of wax, oils, gums, and resins; and of these again how indefinite is the variety!

How are these substances formed by the vegetating organs of plants?

All living vegetables have the power of decomposing water,* and of combining in different proportions the hydrogen of the water with the carbon of the soil, as well as with that of the carbonic† acid of the atmosphere,‡ to form the numberless productions of vegetable nature.§

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* When we decompose water, we can do it only by abstracting its oxygen and liberating the hydrogen, which is easily effected by some combustible bodies. But vegetables perform this process in a different way; they preserve the hydrogen and set the oxygen free. This process of Nature, in the latter instance, has been noticed in a former chapter. See page 66.

Berthollet has remarked that the decomposition of water must always take place to give rise to substances of a resinous character, when the vegetation is performed without the concurrence of foreign bodies. Chemical Statics, vol. ii. 393.

† Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth, covered carefully with sheet lead: he kept it in this state for five years, watering it with distilled water; and at the end of that time the tree weighed 169 pounds three ounces: the earth in which it had vegetated being weighed at the same time, was found to have lost only three ounces. This was repeated by Mr. Boyle with a similar result. See Additional Notes, No. 57.

‡ Organized beings cannot live upon the matter in which they vegetate: Nature, therefore, by making the air their food, has afforded them nourishment without offering violence to their tender organs.

§ Senebier found that plants watered by water impregnated with fixed air grew more luxuriantly than plants watered as usual;

*If carbon and hydrogen enter into the composition of all these substances, how is it that one vegetable affords gum, another resin, another oil, &c. ?**

The infinite variety which there must be in the internal organization of vegetables, to enable different orders to prepare such different substances from the same elements, renders this sub-

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and that when insulated from every substance which could afford it to them immediately, they acquired carbon by the decomposition of carbonic acid gas in the atmosphere. This they take in by the under surface of their leaves, as well as by their roots.

It appears from hence that *solid* matter is not necessary to the growth of vegetables; and that they owe their increase chiefly to the decomposition of water and carbonic acid. See page 67.

* Carbon and hydrogen are not the only principles which enter into the composition of all these substances. Most of them contain a proportion of oxygen also, as may be seen by the following statement:

Olive oil	Carbon	79	Sugar	Carbon	28
	Hydrogen	21		Hydrogen	8
		100		Oxygen	64
					100
Resin	Carbon and hydrogen proportions unknown — Saturated with oxygen.		Gum	Carbon	23
				Hydrogen	11
				Oxygen	65
				Nitrogen & lime	1
					100
Wax	Carbon	82	Saturated with oxygen.		
	Hydrogen	18			
		100			

The formation of resin and wax has lately been explained thus: That when a volatile or a fixed oil is expelled out of plants, and has its surface exposed to the air, the first becomes a resin by losing hydrogen, the second a wax by absorbing oxygen.

ject too intricate and minute for our investigation. We feel the insufficiency of our faculties—"The will of God is the ultimatum of all human knowledge."

Is it known what other substances are employed by nature for the formation and growth of vegetables?

All orders of vegetables are produced from four or five natural substances, viz. caloric, light, water, air, and carbon.* Nature has required

* It has been shown that water and atmospheric air are the natural food of plants. Caloric is necessary to enable vegetables to decompose water and air; and light is equally requisite to give a part of the oxygen of these substances a gaseous form, and to put it in a proper state to be thrown off by the leaves. The other portion of oxygen goes to the formation of sugar and the vegetable acids. The analysis of vegetables confirms this theory; for, however they may be examined, the result is always the production of oxygen, hydrogen, and carbon. Some plants yield also a portion of silex, and others lime; but these no doubt are taken up by the roots from the soil. See Sir Humphry Davy's paper on the silex found in the epidermis of reeds, &c. in Nicholson's Journal for May 1799.

When we consider that the many thousand tribes of vegetables are not only all formed from a few simple substances, but that they all enjoy the same sun, vegetate in the same medium, and are supplied with the same nutriment, we cannot but be struck with the rich economy of Nature, and are almost induced to doubt the evidence of those senses with which the God of Nature has furnished us. That it should be possible so to modify and intermingle a few simple substances, and thence produce all the variety of form, colour, odour, &c. which is observable in the different families of vegetables, is a phenomenon too astonishing for our comprehension. Nothing short of Omnipotence could have provided such a paradise for man.

"Soft roll your incense, herbs, and fruits, and flowers,
In mingled clouds to Him, whose sun exalts,
Whose breath perfumes you, and whose pencil paints."

to the analysis of Bergman, about one forty-fifth of its weight of carbon.*

What quantity of carbon enters into the composition of steel?

Steel is iron combined with about one part of carbon in two hundred of iron.†

How is carbon combined with iron to form plumbago?

Carburet of iron, or plumbago,‡ has been found

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* Cast iron does not owe its brittle qualities to the carbon which is combined with it; for that iron which contains most carbon is found to be the best metal. Cast iron generally contains a portion of phosphuret of iron, and always a quantity of oxygen: these substances give it its hard brittle quality. To convert cast iron into wrought iron the metal is submitted to a long intense heat, by which means the carbon burns, and uniting with the oxygen, both go off in the state of carbonic acid gas. The iron is then carried to the forge hammer, which beats out the phosphuret of iron, and brings the particles closer together. When the iron is required to be pure and good, it undergoes repeated hammering till it is brought to the desired quality.

† To procure steel, nothing more is necessary than to heat good pure iron for several hours in a proper furnace, with charcoal, or any substances proper for furnishing a sufficient quantity of carbon, which is absorbed by the iron in the process. Iron has so great an affinity for carbon, that it is even capable of decomposing carbonic acid in a high temperature. See Philosophical Magazine, vol. ii. where there is an account of a late mode of making steel by fusing soft iron in crucibles with carbonate of lime.

‡ Plumbago is found in great plenty at a place called Borrowdale, in Cumberland. Besides making pencils, it is likewise useful to rub over wooden machinery to prevent friction. See Note ‡, page 270.

According to Fabroni, plumbago is formed in the humid way, at the bottom of certain wells in the kingdom of Naples, from whence it is regularly collected every six months.

Carburet of iron is found also on various parts of the continent. It often occurs in mountains, in the midst of beds of quartz, or calcareous earth. It has lately been found crystallized in octahedrons.

to consist of nearly nine parts carbon to one of iron.

What is the nature of the combination of carbon with zinc?

Carbon combines largely with zinc, but the nature of this combination is not much known.

*You said that carbon formed an acid by its union with oxygen: how is that effected?**

Carbon has so great an affinity to oxygen, that when assisted by heat it will take it from most substances with which it may be combined; in certain proportions they then form carbonic acid gas.†

Plumbago, like charcoal, is indestructible by heat, unless with the presence of atmospheric air. It is therefore much used for making crucibles and portable furnaces. It protects iron from rust, and on that account is rubbed on various ornamental cast-iron works, such as the fronts of grates, &c.

* Take one of those glass receivers generally used for deflagrating the gases; fill it with oxygen gas, and invert it in a shallow pan of water. Then having a piece of ignited cortical part of charcoal ready, suspend it by a wire to the stopper of the receiver, and immerse it quickly in the gas. The charcoal will be seen to burn for a considerable time with the greatest splendour, throwing out the most beautiful corruscations. When the inflammation is over, the oxygen gas will be consumed, and the water will be found to be impregnated with carbonic acid; and if some transparent lime-water be poured in, the whole will become opaque from the carbonate of lime now formed.

† There can be no doubt that carbonic acid is formed by the union of carbon with oxygen; for steel may be made as effectually by the decomposition of carbonic acid, as it can by the direct union of iron with carbonaceous matter.

Carbon takes a gaseous form also by combining with hydrogen and caloric, and forms what is called carburetted hydrogen gas, likewise in the gas discovered by Dr. Priestley, and which Mr Cruick-shank named the *gaseous oxide of carbon.*

What quantity of oxygen is necessary to convert carbon into carbonic acid?

Twenty-eight parts by weight of carbon require 72 parts of oxygen to saturate them; so that 100 parts of carbonic acid are composed of twenty-eight parts of carbon and seventy-two of oxygen.*

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* Oxygen has a greater affinity for carbon than for most other substances. Lavoisier burned small quantities of charcoal in pure oxygen gas in close vessels, and found that a part of this gas was converted into fixed air. He separated this from the rest of the oxygen by means of caustic alkali, and weighed the alkali after it had attracted the fixed air. He also expelled the air again by an acid, and examined its bulk. Thus he learned the weight of the air, and what measure of it had been produced. Then, comparing this weight with that lost by the charcoal which had been consumed, he found it to exceed greatly the weight of the charcoal; and that it was exactly equal to the weight of the charcoal added to that portion of the oxygen gas which had been changed into fixed air. Dr. Black, vol. ii. p. 100.

The composition of carbonic acid has been further proved by analysis, as it has actually been decomposed, and the charcoal exhibited entire. See Mr. Tennant's Experiments on fixed Air, in Phil. Trans. vol. lxxxi. 181. When a diamond is burnt, the proportions are different from the above, for it is the purest carbon we are acquainted with. It requires to form 100 parts of carbonic acid, only 17.88 of diamond, and 82.12 of oxygen. In burning diamond, carbonic acid is the product, and there is *no* residue. One part of charcoal absorbs 2.527 of oxygen, and produces 3.575 of carbonic acid; whereas one part of diamond absorbs more than four parts of oxygen, and produces five of carbonic acid.

More attention has been paid to the appearances in the combustion of the diamond, by Sir George Mackenzie, than by most others who have investigated this subject. See Nicholson's Journal, 4to. vol. iv. 103.

Carbonic acid gas may be readily procured for experiment by pouring a little diluted sulphuric acid into a phial, or a retort, upon a little pulverized chalk. An action will immediately commence; and if one end of a bent tube be made fast in the neck of the phial, and the other brought under the mouth of a jar filled with water, and inverted in a vessel of water, the gas will pass from the mixture into the inverted jar.

What is the specific gravity of carbonic acid?

Carbonic acid can only be exhibited in the form of gas; each cubical inch weighs about half a grain.

What are the properties of carbonic acid gas?

Carbonic acid gas is invisible and elastic, is twice as heavy as atmospheric air,* will mix with vital air, may be combined with water, to which it gives a brisk and acidulous taste,† and will occasion the death of animals that are obliged to breathe it.‡

In what states does carbonic acid exist in Nature?

Carbonic acid is found in Nature in three dif-

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* This gas, on account of its density, may be poured from one vessel to another like water, or may be drawn from a cask by a cock like other fluids. In consequence of its great specific gravity it is frequently found at the bottom of mines, wells, &c. See pages 232, 233.

† In order to saturate water with this gas, it is necessary to subject it to a considerable degree of pressure. The persons who are engaged in making the acidulous soda water have peculiar conveniences for this purpose. Cider, perry, bottled beer, and other fermented liquors, owe their briskness and sparkling to the presence of this gas.

‡ Carbonic acid has also the property of rendering lime soluble in water. As the carbonic acid escapes by exposure to the air, the calcareous matter is precipitated from the water which held it in solution; whence arise the various earthy incrustations found in different parts of the world. Fourcroy has very aptly remarked, that "when natural history was less enlightened by chemistry, springs of this kind were called *petrifying* waters, and were by the vulgar reckoned among the number of miracles."

Some very interesting remarks on the utility of this property of certain waters to dissolve calcareous earth may be seen in Parkinson's Organic Remains, vol. i. page 379.

At Guancavelica in Peru, artists obtain statues and even stones for building, by filling moulds frequently with a mineral water of that district.

ferent states, viz. in gas, in mixture, and in chemical combination; it is perhaps the most abundant of all native acids.*

What instances are there of its natural existence in the state of gas?

It is found in the proportion of about one part† by measure, in every thousand parts of atmospheric air; also in caverns and mines, where it is called the choke damp.‡

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* Plants of all kinds give out carbonic acid gas while growing in the shade: but when assisted by the rays of the sun, there is reason to think that the plants have the power of decomposing this acid: for then the leaves give out only oxygen gas. Annales de Chimie, tom. xiii. p. 318.

Mons. Saussure has shown that when vegetables decompose carbonic acid gas, they throw off only half of the oxygen; and that the other half, with the whole of the carbon, enters into the composition of the plant. He also says, that the leaves absorb oxygen gas in darkness, and emit an equal quantity when exposed to the light. If this account of vegetation be correct, growing vegetables deteriorate the atmosphere in the night and purify it in the day. The roots, wood, and petals perform no inspiration. See Phil. Mag. vol. xx. 307.

† The use of this gas in atmospheric air is not accurately known. Perhaps the large quantity of carbonic acid which is perpetually forming by the process of respiration and combustion, seizes the putrid exhalations which arise from the earth, and preserves the atmosphere from being contaminated with them. We know that *carbon* has the property of uniting chemically with putrid miasmata, and rendering them innoxious. It seems likely, then, that a small portion of carbonic acid gas is diffused throughout the atmosphere, in order that it may be ready to arrest every malignant vapour at the moment of its formation by the putrefactive process. Without some such contrivance we should be in perpetual danger of pestilential contagion.

‡ The floor of the Grotto del Cane, in Italy, is lower than the door, and this hollow is always filled with fixed air, which can rise no higher than the threshold, but there flows out like water. It has been a common practice to drive dogs into this cavern, where they suffer a temporary death, for the entertain-

What instances are there of carbonic acid being found mixed with fluids?

It is abundant in Spa-water, and in some other acidulous waters.*

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ment of the passengers; but a man enters with safety, because his mouth is far above the surface of this deleterious air. From the loss of so many dogs in this cavern it acquired the name of the Grotto del Cane. The lake of Avernо, which Virgil supposed to be the entrance to the infernal regions, evolves so large a quantity of this gas, that birds flying over it drop with suffocation. Fatal accidents have happened to persons who have incautiously descended into brewers' vats, and wells, before they have been purified from this gas.

Carbonic acid gas so often occupies the bottoms of wells, that workmen ought never to venture into such places without previously letting down a lighted candle. If the candle burns, they may enter it with safety; if not, a quantity of *quick lime* should be let down in buckets, and gradually sprinkled with water. As the lime slakes, it will absorb the carbonic acid gas, and the workmen may afterwards descend in safety.

Fatal accidents often happen from burning charcoal in chambers; as whenever charcoal is burned this gas is formed. Workmen have also lost their lives by sleeping too near lime-kilns where this gas is extricated in abundance. Whenever persons are discovered in such situations, or are suffering from the effects of carbonic acid gas, the same means should be made use of as are directed by the Humane Society, in cases of apparent death from drowning: or when it can be done without loss of time, atmospheric air, or even pure oxygen gas, should be forced into the lungs. I have known galvanism sometimes employed in such cases with the best effects.

Dr. Henry has suggested to naturalists, that butterflies and other insects, the colours of which it is desirable to preserve for the purpose of cabinet specimens, may be suffocated in carbonic acid gas, better than by the common mode of killing them with the fumes of sulphur.

Carbonic acid gas has been given medicinally with success, and has proved a powerful antiseptic. Meat which has been sealed up in it has been known to have preserved its texture and appearance for more than twenty years.

* These waters have a pleasant light acidity and briskness, and sparkle in the glass like fermented liquors; which is well known to be the case with water when artificially impregnated

what substances is carbonic acid found chemi-combined?

arbonic acid is found in all parts of the world eat plenty, in combination with the alkalies, arths, and in stones; particularly in chalk, stone, and marble.*

hat is the effect *of the combination of carbonic ?*

arbonic acid renders mild and salutary some ne most acrid and destructive of all known tances.†

ow is the carbonic acid separated from alkalies earths?

arbonic acid may be disengaged by all the

other acids; but it is usually separated from alkalies by the addition of quick-lime, which absorbs this acid, and thus is converted into carbonate of lime.*

How is carbonic acid usually procured for chemical purposes?

Carbonic acid gas may be collected in abundance from the surface of fermenting liquors; but it is more commonly obtained by pouring sulphuric acid upon a mixture of chalk, or marble and water.†

How do you account for the production of carbonic acid gas in the process of fermentation?

In all vinous fermentations a decomposition of the saccharine matter takes place; and a part of the disengaged oxygen, uniting with a part of the carbon of the sugar, forms carbonic acid.‡ A

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* Though the alkalies readily part with their carbonic acid to caustic calcareous earth, yet they have a great affinity to this acid, as may be shown by the following interesting experiment: Fill a jar with carbonic acid gas, then pour into it a small quantity of a solution of *caustic* potass, or soda; and having tied the mouth over with a wetted bladder, move the vessel so as to spread the alkali over its inner surface, when a vacuum will be quickly formed by the absorption of the gas, which will appear by the bladder being pressed inwards by the weight of the atmosphere. If this experiment be made in a glass vessel, its surface will be seen covered with crystals of the alkali, as the carbonic acid always promotes the crystallization of the fixed alkalies.

† This process beautifully demonstrates the indestructibility of matter: in it we remark that the gas which has bound together the massy rock for a thousand years, is still carbonic acid, and is as capable of forming a variety of combinations as any carbonic acid would be if recently produced. How economical is Nature in all her proceedings! See Additional Notes, No. 25.

‡ It has been matter of surprise to me that no advantage has

mposition also of part of the water of solution aps promotes the process.

hat is the cause of vinous fermentation?

he cause of vinous fermentation is not well rstood: but it appears to be a spontaneous motion that takes place on the decomposition egetable substances, in certain favourable circstances of temperature and solution; and it process which Nature employs for their dection.*

hat circumstances are necessary to produce vinous entation?

he presence of vegetable matters, of water, ugar,† a certain degree of heat, and free

taken of the vast quantities of carbonic acid gas, which are

egress for the carbonic acid to escape as it is generated.*

Can you at all account for the change which is effected in saccharine liquors by fermentation?

By the process of fermentation the sugar, which is a vegetable oxide,† parts with a portion of its oxygen to form carbonic acid, and becomes converted into alcohol‡ by being thus partially deoxidized.

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a small quantity of potash; and the addition of either prevented fermentation. See Mr. John Thomson's Notes to Fourcroy, vol. iii. 128; also Dr. Rollo on Diabetes; and the Additional Notes to this volume, No. 49.

* To produce vinous fermentation, it is necessary that the matters subjected to that process should be placed in a temperature not lower than 55 degrees of Fahrenheit. No kind of fermentation is ever known below the freezing point.

† Lavoisier having analysed sugar, found that it was composed of hydrogen, oxygen, and carbon, in the following proportions. Hydrogen 8lbs. oxygen 64lbs. carbon 28lbs. in every 100 pounds weight of sugar. Lavoisier's Elements, 188. Having subjected 100lbs. of sugar to fermentation, he found the products, (viz. alcohol, carbonic acid, and acetous acid,) when analysed, contained the precise quantities of hydrogen, oxygen, and carbon, which were contained in the original sugar. The particular detail which he has given of these experiments is extremely interesting. Ibid. p. 185 to 197. In consequence of the results which were obtained, he remarks, "The effect of the vinous fermentation upon sugar is thus reduced to the mere separation of its elements into two portions: one part is oxygenized at the expense of the other, so as to form carbonic acid; while the other part, being deoxygenized in favour of the former, is converted into the combustible substance called alcohol."—Ibid. p. 196.

‡ Alcohol, according to the analysis of Lavoisier, is composed of carbon about . . . . . 30 parts.
Hydrogen . . . . . 7.5 ditto.
Water . . . . . 62.5 ditto.

100.0

But as this analysis was made by burning alcohol in oxygen

oes sugar then become spirit of wine, or alcohol, ly by losing a part of its oxygen?

o: it parts with a portion of its carbon at the e time, in the form of carbonic acid gas, and w arrangement of the remaining principles of the sugar, and of the water in which it is olved, takes place, furnishing an increase ortion of hydrogen, in order to form vinou or.*

ndeavour to recollect the different properties harcoal, which you have enumerated in this ter.

harcoal appears to be indestructible by age; not in the least altered by the most intense , if heated in *closed* vessels; when burnt in ospheric air, it becomes converted into carbo-

its indestructibility and its antiseptic qualities. The other peculiar and surprising properties of charcoal were reserved for the discoveries of the present age; for these we are most especially indebted to the labours and genius of Black,* Priestley,† Cavendish, Lavoisier, Guyton, Tennant, and Berthollet, and to the gradual developement of the present improved system of chemistry.

What reflections naturally present themselves on the consideration of the various properties of charcoal and the other simple combustibles?

This subject, when considered in all its connexions, is calculated to produce the most profound admiration; and serves to convince us of the unbounded comprehension of that Divine mind, which, in the act of creation, could foresee

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* In the year 1755 Dr. Black discovered the acid gas which is thrown off from fermented liquors and from mild calcareous earth. He called it *fixed* air.

† Dr. Priestley explained the effect of charcoal in decomposing nitrous acid, examined the gas that is thrown off in this decomposition, and pointed out the necessity of distinguishing the different gases from common air; for which the Royal Society awarded him an honorary prize.

In the years 1766 and 1767 Mr. Cavendish published papers in the Philosophical Transactions on the nature of elastic fluids, in which he announced that he had produced fixed air by the burning of charcoal. This assurance called the attention of all chemists to that surprising substance, and was the forerunner of the many discoveries which have since been made respecting its properties, &c.

Lavoisier pointed out the nature of the action of charcoal in reducing metallic oxides; investigated the nature of the combustion of the diamond; announced the exact quantity of carbon in carbonic acid; and the production of carbonic acid by the decomposition of water with ignited charcoal.

and appoint such important effects to result from the combinations and changes of the most inodorous and insipid substances. We also learn, that all the works of the Creator are perfect; and perceive with astonishment, that they are composed of elements which are in themselves incapable of destruction.*

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* See Additional Notes, No. 25 and 37.

CHAPTER X.

OF METALS.

WHAT are the characteristics of the metals?

The general characters of the metals are, hardness, tenacity, lustre, opacity, fusibility, malleability, and ductility: but some metals are neither malleable nor ductile.*

How are the metals procured?

They are generally taken from the bowels of the earth,† in a state of combination either with other metals,‡ with sulphur, oxygen, or with

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* In the former editions of this work *"great specific gravity"* was mentioned as one of the characteristics of the metals; but as metallic substances have lately been discovered by Sir Humphry Davy, which have specific gravities less than that of water, this character could no longer be given to that class of bodies.

† Metals are generally found in mountainous countries, in such as form a continued chain; but the metallic part of a mountain usually bears but a small proportion to its whole contents. Granite rocks seldom contain any metallic ores.

It is deserving of notice, that if minerals had been placed on the *surface* of the globe, they would have occupied the greatest part of the earth, and would have prevented its cultivation. Their being deposited *below* is a proof of management and design worthy of that Being who could furnish so great a variety of this class of bodies.

‡ When metals are found combined with other metals they are called native alloys.

A table of the orders and the genera of the ores of metals may be seen in Dr. Thomson's Chemistry, vol. iv. 19.

acids;* though a few of them have occasionally been found in a state of purity.†

By what methods are the metals purified from these substances?

The metals are purified from their ores by various means; such as washing, roasting, fusion,‡ &c.; but the method must always be regulated by the nature of the ore to be assayed.§

How many metals are there?

There are twenty-seven‖ distinct metals, which possess properties very different and distinct from each other.¶

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* The sulphuric, muriatic, phosphoric, and carbonic acids are those which are generally found in combination with metals.

† Among those metals which most frequently occur in the *metallic* state may be ranked quicksilver. In Bishop Watson's Chemical Essays mention is made of such a mine in this country, viz. at Berwick in Northumberland, in the *midst* of that town; and Mr. Hume, a native of that place, assures me that he was an eye witness to this fact.

‡ The analysis of metallic ore in the great, is always performed by fire, and this is called the *dry* way; but the more accurate analysis is effected by means of various chemical reagents which modern chemistry has applied to that purpose, and is termed the *moist* way. Before the time of Bergman every kind of analysis of minerals was conducted by fire: he was the first chemist who resorted to the method of solution in acids, which is easy, simple, and effectual.

§ Those who wish to investigate this subject may find ample information in Schlutter's work on mineralogy; in Henkel's Pyritologia; in Cramer on Metals; in Kirwan's Mineralogy; and in Klaproth's Essays. Some general ideas on the subject may be collected from a well written paper of Dr. Thomson's in the second edition of his System of Chemistry, vol. iv. 173.

‖ The several metalloids of Davy are not included in this enumeration: it will be necessary to know more of their respective properties before we can class them with the metals.

¶ For a knowledge of most of the metals, we are indebted to the more perfect modes of analysis which modern chemistry has afforded. The ancients were acquainted with only seven of

How are the metals classed by modern chemists?

They are divided into two classes. The one contains the malleable, the other the brittle metals. This last class is sometimes subdivided into two others, viz. those which are easily, and those which are difficultly fused.

How many malleable metals are there?

Ten;* viz.

1. Gold,†	6. Iron.
2. Platina,	7. Tin.
3. Silver,	8. Lead.
4. Mercury,	9. Nickel,
5. Copper,	10. Zinc.

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these metals. The properties of these were tolerably well known to the early chemists, who acquired their knowledge from the alchymists. These infatuated people tortured silver, mercury, copper, iron, tin, and lead, in every way they could devise, in order to convert them into gold. Alchymy was probably introduced into Europe by the crusaders, whose minds were prepared for the reception of any delusion. In all likelihood they picked up the idea of the transmutation of metals on their return from Palestine; and as error generally operates more powerfully than truth with such fanatics, they deluged their native country with these absurdities. The vain and conceited Paracelsus, a Swiss physician, was one of the last of the alchymists. He announced to the world that he had discovered a medicine, which would render man immortal: but worn out by his debaucheries and excesses, he gave the lie to this assertion; for he himself died, in the year 1534, at the age of 41.

In the reign of Henry IV. an act was passed to make it felony to transmute metals. This act was repealed in consequence of the suggestions of Mr. Boyle, who was aware of its absurdity.

* In this enumeration I have purposely omitted palladium, rhodium, iridium, and osmium, the four metals found in the ore of platina, as they occur in small quantities, and their properties have not yet been sufficiently examined, and it is *possible* that they may be merely alloys of other metals. What is known respecting them, may be seen in vol. iii. of Murray's System of Chemistry, p. 160 to 197.

† Of these metals, the three first have been called noble or

low many brittle metals are there?

here are thirteen metals in this class which are her malleable nor ductile.*

Which are the easily fusible of the brittle metals?

here are four fusible brittle metals; viz.

1. Bismuth,
2. Antimony,
3. Tellurium,
4. Arsenic.

Which are the brittle metals that are fused with culty?

here are nine of these metals; viz.

1. Cobalt,
2. Manganese,
3. Tungsten,
4. Molybdenum,
5. Uranium,
6. Titanium,
7. Chromium,
8. Columbium, or Tantalium,†
9. Cerium.

will be necessary to consider each of these metals

Where is gold found?

Gold is found in Peru and in some other parts of the world. It generally occurs in a metallic state, and most commonly in the form of grains.*

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to make up the thickness of one inch; whereas 1½ million leaves of common printing paper make up near ¼ of a mile.—Vol. ii. 654. According to Fourcroy, the ductility of gold is such, that one ounce of it is sufficient to gild a silver wire more than thirteen hundred miles long.

Such is the tenacity of gold, that a wire $\frac{1}{72}$'h of an inch in diameter will support a weight of 500 pounds without breaking.

Gold melts at 32° of Wedgwood, and, if pure, is a beautiful green colour when in fusion. By means of a powerful lens it may be volatilized.

Gold becomes much harder by an union with a small quantity of copper.

Gold leaf, thrown into oxymuriatic acid gas at the temperature of 70° or 80°, takes fire and burns with great brilliancy.

Fulminating gold is made by diluting a saturated solution of gold with three times it measure of distilled water, and precipitating the oxide by solution of ammonia, *gradually* added. The precipitate, when dried on a filter, forms this fulminating powder, which detonates by heat, or friction. A shocking account is related by Macquer, of a person losing both eyes, by the bursting of a phial containing fulminating gold, at the house of Baumé, and which exploded by the friction of the glass stopper against a minute quantity that adhered unobserved to the neck of the bottle. This accident ought to deter every one from making experiments with this dreadful compound.

Gold may be known from all other metals by its bright yellow colour, and its weight. Its specific gravity is 19.3; when heavier it must be combined with platina; when lighter, and of a deep yellow colour, it is alloyed with copper; if of a pale colour, with silver.

This noble metal may be detected when in solution, by green sulphate of iron: this precipitates it of a brown colour, which soon changes to the colour of gold.

* Gold frequently occurs in the ores of other metals, but it is chiefly found in the warmer regions of the earth. It abounds in the sands of many African rivers, in South America, and in India. Several of the rivers in France contain gold in their sands. It has also been discovered in Hungary, Sweden, Norway, and Ireland. Near Pamplona, in South America, single labourers have collected upwards of 200*l.* worth of wash-

What is the effect of oxygen *upon gold?*

Gold has so little affinity for oxygen, that it cannot be easily oxidized like the other metals; this may however be effected by amalgamating it with mercury, and applying heat.*

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gold in a day. In the province of Sonora the Spaniards discovered a plain fourteen leagues in extent, in which they found wash-gold at the depth of only 16 inches; the grains were of such a size that some of them weighed 72 ounces, and in such quantities, that in a short time, with a few labourers, they collected 1000 marks, (equal in value to 31,219*l.* 10*s.* sterling,) even without taking time to wash the earth that had been dug. They found one grain which weighed 132 ounces. This is deposited in the Royal Cabinet at Madrid, and is worth 500*l.* Dr. Black, ii. 694.

The native gold found in Ireland was in grains, from the smallest size up to between two and three ounces. Only two grains were found of greater weight, one of which weighed five, and the other 22 ounces. See Phil. Trans. for 1796.

Gold mines were formerly worked in Scotland; and indeed now, grains of this metal are often found in brooks of that kingdom, after a great flood. It has been said, that, at the nuptials of James V. covered dishes, filled with coins of *Scotch gold*, were presented to the guests by way of dessert.

Some of the French chemists assert that they have absolutely discovered gold in the ashes of vegetables.

* Gold has generally been thought susceptible of two degrees of oxidizement; the purple, and the yellow oxide; but neither of them is ever found native. See a note on metallic oxides and the formation of metallic salts, chap. xi.

It was formerly imagined that gold could not be oxidized by atmospheric air, even in the highest temperature; it has however been proved, that the heat produced by an electrical or galvanic discharge is sufficient to effect it, and to convert the whole of the metal to the *purple* oxide.

According to Fourcroy, gold and silver may be oxidized by triturating them in a mortar with saliva. This method is frequently made use of for oxidizing mercury. Saliva has a great affinity for oxygen. Nature seems to have endowed it with this property, that it may absorb oxygen from the air to impart it to the food.

"If gold and silver should, when heated with other metals, undergo a slight degree of calcination by such a process, a

What salts *of gold are there?*

There is only one salt of this metal that is much known to chemists, viz. the *muriate of gold*,* which is obtained in small crystals, and is very soluble in water. Many other salts may

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stronger heat alone makes them immediately resume their pure and metallic form. The allusion therefore to this quality of the precious metals, to illustrate the triumph of a good heart over misfortune, is peculiarly beautiful: and, as this is to be found in the book of Job, the discovery of the oxidizement and reduction of these metals must be very ancient."

The attraction of gold and silver for oxygen is so slight, that the rays of the sun alone will deoxidize the oxides of these metals.

The oxides of gold may be reduced by hydrogen gas, or sulphurous acid gas. If white satin ribbon, or silk, be moistened with a diluted solution of gold, and, *while moist*, exposed to a current of either of these gases, the metal will immediately be reduced, and the silk become gilt with a regular coat of gold. In this way any ornamental figures may be laid upon silk, the gilding of which will be very permanent. For the rationale of this process consult Mrs. Fulhame on Combustion, to whom we are indebted for the idea.

* This salt is formed by dissolving gold in nitro-muriatic acid, and leaving the solution at rest for the salt to crystallize. In this process the nitric acid affords oxygen to the metal; and as the metal becomes oxidized, the oxide is dissolved by the muriatic acid. Nitro-muriatic acid and oxymuriatic acid are the only acid solvents of this metal. A solution of muriate of gold, when concentrated by evaporation, yields beautiful yellow crystals not unlike *topazes*.

If ether be added to a solution of muriate of gold, the gold will leave the acid, and float upon its surface, combined with the ether. This ethereal solution has lately been used by Mr. Stodart and Mr. Savigny for defending their lancets and other surgical instruments from injury by a damp atmosphere. See Nicholson's Journal. It was formerly used in medicine under the name of *portable gold*. In those days of credulity it was generally prescribed to all patients who could furnish the apothecary with gold enough to make a sufficient quantity of the medicine to ensure a cure. The account which John Glauber

formed with gold, but nothing at present is
wn either of their properties or uses.*

What are the uses *of gold?*

old is used for jewellery, for plate, and for cur-
coin; but for these purposes it is generally
ed.† It is employed in various ways in the
‡ Gold is also used to be spread over other
ls to preserve them from tarnishing or rusting,
old does not become oxidized by exposure to
spheric air.§

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of this celebrated panacea at the end of his "Treatise on
ophical Furnaces," 1651, page 393, will afford the reader
entertainment.

As there are thirty-two acids, each of which is probably ca-
of uniting with each of the metals, the number of metallic
hat may be formed by art will amount to many hundreds:
this elementary work, only those most known will be no-

What salts *of gold are there?*

There is only one salt of this metal that is ich known to chemists, viz. the *muriate of d,** which is obtained in small crystals, and very soluble in water. Many other salts may

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ager heat alone makes them immediately resume their pure metallic form. The allusion therefore to this quality of the ious metals, to illustrate the triumph of a good heart over ortune, is peculiarly beautiful; and, as this is to be found in ook of Job, the discovery of the oxidizement and reduc- of these metals must be very ancient."

e attraction of gold and silver for oxygen is so slight, the rays of the sun alone will deoxidize the oxides of these ls.

e oxides of gold may be reduced by hydrogen gas, or urous acid gas. If white satin ribbon, or silk, be ened with a diluted solution of gold, and, *while moist*, ed to a current of either of these gases, the metal will diately be reduced, and the silk become gilt with a r coat of gold. In this way any ornamental figures be laid upon silk, the gilding of which will be very anent. For the rationale of this process consult Mrs. nie on Combustion, to whom we are indebted for the

* This salt is formed by dissolving gold in nitro-muriatic and leaving the solution at rest for the salt to crystallize. is process the nitric acid affords oxygen to the metal; and e metal becomes oxidized, the oxide is dissolved by the atic acid. Nitro-muriatic acid and oxymuriatic acid are the acid solvents of this metal. A solution of muriate of gold, n concentrated by evaporation, yields beautiful yellow crys- not unlike *topazes*.

ether be added to a solution of muriate of gold, the gold leave the acid, and float upon its surface, combined with ether. This ethereal solution has lately been used by Mr. lard and Mr. Savigny for defending their lancets and other ical instruments from injury by a damp atmosphere. See bbon's Journal. It was formerly used in medicine under name of *portable gold*. In those days of credulity it was erally prescribed to all patients who could furnish the apo- ary with gold enough to make a sufficient quantity of the dicine to [illegible] account which John Glauber

ormed with gold, but nothing at present is n either of their properties or uses.*

hat are the uses *of gold?*

old is used for jewellery, for plate, and for cur- coin; but for these purposes it is generally ed.† It is employed in various ways in the ‡ Gold is also used to be spread over other ls to preserve them from tarnishing or rusting, old does not become oxidized by exposure to spheric air.§

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of this celebrated panacea at the end of his "Treatise on *ophical Furnaces*," 1651, page 393, will afford the reader entertainment.

s there are thirty-two acids, each of which is probably ca- of uniting with each of the metals, the number of metallic hat may be formed by art will amount to many hundreds: this elementary work, only those most known will be no-

What is the origin *of silver?*

Silver is found in various parts of the world in a metallic state:* also in the states of a sulphuret, a salt, and an oxide.†

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purple, called the *purple precipitate of Cassius*. This also is used by the potter in painting on porcelain. Sulphuret of potass will likewise dissolve gold. Some have thought that Moses made use of this process to render the calf of gold, adored by the Israelites, soluble in water. Stahl wrote a long dissertation in order to prove that this was the case. See Additional Notes, No. 29.

* Silver was used in commerce eleven hundred years before the foundation of Rome. Genesis xxiii. 16.

† Native silver is found chiefly in the mines of Potosi. Sulphuret of silver occurs in the silver-mines of Germany, Hungary, Saxony, and Siberia. Oxides of silver are also common in some of the German silver mines. Silver has lately been found in a copper-mine in Cornwall. See Mr. Hitchen's paper in Philosophical Transactions, vol. xci. 159. Most of our lead mines also afford it, particularly some of the lead mines in Scotland. In the county of Antrim in Ireland there is a mine so rich, that every thirty pounds of lead-ore is said to produce one pound of silver. "In the museum of the Academy of Sciences at Petersburg, is a piece of *native* silver from China, of such firmness, that coins have been struck from it, without its having passed through the crucible."—Storch's "Picture of Petersburgh," p. 330.

By the silver which was produced from the lead mines in Cardiganshire, Sir Hugh Middleton is said to have cleared two thousand pounds a month, and that this enabled him to undertake that great work of bringing the New River from Ware to London. In 1637, a mint was established at Aberystwith for coining Welsh silver.—Bishop Watson.

Aristotle says, that some shepherds discovered the method of working the silver mines of Spain; for, having occasion to clear a quantity of land by burning down the wood, they found fused silver produced by the operation of the fires.

It may be ascertained whether an ore contain silver, by pulverizing it and dissolving it in nitric acid, and afterwards adding a little muriatic acid. Should it contain any silver, the muriatic acid will instantly combine with the whole of it, and precipitate it from the nitric solution in white flakes of muriate of silver. In order to know the proportion of silver in any given

What is the nature *of silver?*

Silver is a heavy, sonorous, brilliant, white metal;* exceedingly ductile, and of great malleability and tenacity. It possesses these latter properties in so great a degree, that it may be beaten into leaves much thinner than any paper,† or drawn out into wire as fine as a hair, without breaking.

What is the effect of oxygen *upon silver?*

Silver cannot be oxidized by atmospheric air, unless exposed to an intense heat; but the oxide of silver may be procured by dissolving the metal

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quantity of ore, collect this precipitate on a filter, heat it red, and weigh it accurately. Every 100 grains of this precipitate contains 73 grains of pure silver.

* The specific gravity of silver is 10.500. When perfectly pure it is a very soft metal.

† Fifty square inches of silver leaf weigh not more than a grain. The silver wire used by astronomers is no more than half as thick as a fine human hair.

Silver melts at 28° of Wedgwood. In a temperature much higher it becomes volatilized.

Silver, gold, and platina require the heat of a powerful burning lens in order to put them in a state of combustion.

Silver has such an affinity for muriatic acid, that this acid is employed as a test for discovering silver in solution.

Silver readily combines with sulphur. According to Mr. Hatchett, those who rob the public, by diminishing the current silver coin, make use of the following method. "They expose the coin to the fumes of burning sulphur, by which a black crust of sulphuretted silver is soon formed, which, by a slight but quick blow, comes off like a scale, leaving the coin so little affected, that the operation may sometimes be repeated twice or thrice, without much hazard of detection."—Philosophical Transactions, vol. lxxxviii.

To know when silver is pure, heat it in a common fire, or in the flame of a candle: if it be alloyed, it will become tarnished; but if it be pure silver, it will remain perfectly white.

in an acid,* and then precipitating it by an alkali. There are two oxides of silver at present known, viz. the gray, and the white oxide.†

What salts *are there of silver?*

The nitrate of silver‡ is best known; but in analysis the sulphate of silver is also a most useful

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* The proper solvent for silver is the nitric acid, and, if the silver be pure, the solution will be colourless. If it contain gold, that metal will be precipitated as the silver dissolves. In dissolving dollars, I have sometimes seen a considerable quantity of gold precipitated. The Spanish dollars, I believe, always contain gold.

Silver is dissolved in nitric acid for forming the metallic tree. It is a pleasing experiment attended with very little expense. A metallic crystallization somewhat similar may be made by suspending a piece of zinc in a solution of acetate of lead. See Gren's Chem. vol. ii. 382. Thomson's Fourcroy, vol. ii. 487.

† Metals can combine only with one certain portion of oxygen, to give the first degree, and if that portion of oxygen be not present, the metal will not become oxidized. But, when a metal is susceptible of two or more degrees of oxidizement, it becomes first oxidized with the smaller quantity of oxygen: after this, the new combination has a further attraction for oxygen, and the second degree of oxidizement takes place, &c. &c.

Silver, when reduced to a liquid amalgam with mercury, is liable to be oxidized at the temperature of the atmosphere. This is owing to its having lost its natural coherence by that operation. The same may be said of an amalgam of gold.

‡ This salt is kept in chemical laboratories as a test for the muriatic acid. When melted, and run in moulds, it forms the lunar caustic of the apothecary. When dissolved in water and left at rest, it crystallizes in brilliant transparent plates of different forms. Though the solution is as pale as pure water, it will stain the skin and other animal substances of an indelible black. It is employed to dye human hair; for staining marbles and jaspers; and for silvering ornamental work. This salt is the most powerful antiseptic known. One ounce of it dissolved in 12,000 ounces of water will preserve the water from putrefaction for ever, and it may any time be separated therefrom in a few minutes, by adding a small lump of common salt. Dr. Black, vol. ii. 661. An ingenious method of silvering ivory by

test: many other salts of this metal* may likewise be formed. The muriate and the carbonate of silver are both found native.†

What are the uses of silver?

Silver is used chiefly for ornamental work, for domestic utensils,‡ and for current coin; but for these purposes it is generally alloyed with copper,§ without which it would not have sufficient hardness to sustain much wear.‖

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the solution of this salt may be seen in Count Rumford's Phil. Papers, vol. i. 22.

A solution of nitrate of silver mixed with a little gum water forms the *indelible ink* used in marking linen.

* Hyperoxygenized muriate of silver has been used in making fulminating powder. If this salt be mixed with half its weight of sulphur, and struck slightly, it detonates with prodigious violence. The flash is white and vivid, and the silver is reduced. Dr. Thomson, ii. 530.

What is usually called *fulminating silver*, is made by a different process; but as it is so dangerous an article, it was thought best to omit giving directions for preparing it, in a work designed principally for the use of the young and the inexperienced. It is so dangerous, that a minute quantity only can be made at a time with safety, and even that could not be removed to a phial, without the utmost risk of shattering the glass into ten thousand pieces by its detonation.

† Muriate of silver has been found crystallized in Saxony, and in South America. Carbonate of silver has been found in masses in Suabia.

‡ Pliny observes, that such was the luxury of the Romans, that it was simply reckoned a piece of elegance to consume in the ornaments of coaches, and in the trappings of horses, metals which their ancestors could not use even in drinking-vessels, without being astonished at their own prodigality. Nero and his wife shod their favourite horses with gold and silver. Bp. Watson, vol. iv. 188.

§ Our standard silver is formed with 15 parts pure silver, and one part copper.

‖ Silver is also used for plating other metals, for silvering dial-plates, &c. An account of these different processes may be found in Imison's School of Arts.

How is platina *procured?*

Platina is found in grains, in a metallic state, at St. Domingo, and at Santa Fé in Peru.*

What is the nature *of platina?*

Platina is the heaviest of all the metals;† is nearly as white as silver, and is difficultly fusible, though by great labour it may be rendered malleable, so as to be wrought into utensils like

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* Charles Wood was the first person who brought any of this metal to England. He brought it from Jamaica in the year 1741, and published an account of his experiments upon it in the Phil. Trans. for 1749 and 1750. Platina in the language of Peru means *little silver.*

Platina has lately been discovered in an ore of silver found in Estremadura. It exists in this ore in its metallic form; and as none of the new metals found with the South American platina are here present, the platina may be obtained from this ore at a trifling expense.

The ore of platina contains no less than nine different substances, viz. silex, iron, lead, copper, platina; and four new metals, which are called iridium, osmium, rhodium, and palladium. It is possible, however, as has been hinted before, that these latter may be merely alloys of other metals, as they have been found nowhere but in the ore of platina. Platina itself is indeed an alloy: for even after fusion it is magnetic from the presence of iron. The properties of these new metals have as yet been but little investigated. For the methods of analysing the ore of platina, consult Dr. Wollaston's and Mr. Tennant's papers in the Philosophical Transactions, which are the best treatises on this metal.

Platina may be distinguished from all other metals by adding a solution of muriate of ammonia to a solution of the metal in nitro-muriatic acid, when a red-coloured precipitate will instantly appear. This is the only means yet known to discover when gold has been alloyed with this metal. Gold is generally known, if weighed hydrostatically, by its specific gravity; but if it be alloyed by platina, some other test is necessary, as platina has a greater specific gravity than gold.

Some of the methods which have been employed to procure platina in a state of purity may be seen in Thomson's Chemistry, in the Phil. Trans. and other modern publications.

† The specific gravity of hammered platina is 23.66, which

metals.* It will resist the strongest heat of
res without melting,† and, like iron, is capa-
f being welded when properly heated.

hat is the effect of oxygen *on platina?*

e oxygen in atmospheric air has no effect
platina,‡ unless when assisted by an intense
but the oxide may be procured by dissolving
etal in nitro-muriatic acid, and precipitating
an alkali.§

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e than double that of lead. It may always be known
ther metals by this superior specific gravity, it being the
st body in nature.

r. Knight was one of the first of the modern chemists
ointed out a way to render this metal malleable. See his
in Philosophical Magazine, vol. vi. 1. Another method
omplish this end has been published by Mr. Tilloch, in
enty-first volume of the same work.

ina has been drawn into wire less than the two-thousandth
an inch in diameter.

What salts *are there of platina?*

A variety of salts may be formed with the oxide of this metal, but none of them have yet been brought into much use.* No salt of platina has yet been found native.

What are the uses *of platina?*

Platina has hitherto been chiefly used for chemical utensils, such as crucibles, spoons, &c.† and to make specula for telescopes. It has also been beaten into leaves, and applied to porcelain‡

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* In order to form any salt of platina, the metal must be previously dissolved in nitro-muriatic acid or oxymuriatic acid, these being the only menstrua that will act upon it. And in making the nitro-muriatic acid, three parts of muriatic acid should be mixed with one part of nitric acid; Proust having determined that this mixture dissolves the largest proportion of the metal. A solution of any other salt is then to be added, and by double affinity the new salt required may be obtained. Thus a solution of phosphate of soda would probably give a phosphate of platina.

† The important uses to which this precious metal may be applied can be easily conceived, when it is considered that it unites the indestructibility of gold to a degree of hardness almost equal to that of iron; that it resists the action of the most violent fire, and also of the most concentrated acids. Vessels of capacity made with this metal, must, however, always come extremely dear, as it is necessary to solder them with gold. There is also another disadvantage attending the use of this metal for chemical purposes, which is, that it is corroded by caustic alkalies. Indeed crucibles of platina have been eroded by analysing minerals in them which have contained some of the neutral salts.

‡ A very neat method to cover other metals with platina was lately discovered by Mr. Stodart, who found that, like gold, it may be taken up from its solution by sulphuric ether. See Nicholson's Journal for the year 1805. Where the expense of ether would be an objection to its use, good oil of turpentine may be employed in its stead.

It is said that M. Strauss has, after many experiments, suc-

in the manner of leaf gold. Its oxide is used in enamel painting.*

Where is mercury *found?*

Mercury is brought to Europe from the East Indies, and from Peru;† but it is found in greater

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ceeded in applying platina to the coating of copper with as much ease as the common operation of tinning. The durability of this metal, and its resistance to acids and saline matters, will render this a most valuable discovery.

An alloy of copper with this metal is likely to prove very valuable, as it is malleable and ductile, is susceptible of a fine polish, and receives no tarnish of its lustre by exposure to the air.

Crude platina melted with copper and silver affords a compound that oxidizes but little by muriatic or nitric acid, and which when drawn into wire is highly elastic, and very useful for springs that are designed to be exposed to the action of the atmosphere. An alloy of this kind is employed in the manufacture of Mr. Stansbury's new patent locks, and is likely to give them great durability.

By melting 15 parts of gold with one part of purified platina, Mr. Hatchett produced a yellowish-white alloy, extremely ductile, and very elastic; so much so, that he is of opinion it might be used with great advantage in making watch springs.

* Klaproth proposed the use of platina in enamel-painting, instead of silver, which is liable to tarnish. Platina has not this inconvenience; and when intermixed with figures of gold has a beautiful appearance. Besides, various coloured alloys may be formed by the union of the two metals so as to produce a great variety of shade of colour. Directions for using platina in this way may be seen in the 17th volume of the Philosophical Magazine.

† The quicksilver mine of Guanca Velica, in Peru, is 170 fathoms in circumference, and 400 deep. In this profound abyss are seen streets, squares, and a chapel where religious mysteries on all festivals are celebrated. Millions of flambeaux are continually burning to enlighten it. The mine generally affects with convulsions those who work in it. Notwithstanding this, the unfortunate victims of an insatiable avarice are crowded all together, and plunged *naked* into these abysses.

abundance at Almaden* in Spain, where it is extracted from the ore by distillation.†

What is the nature of mercury?

Mercury, in the temperature of our atmosphere, is a fluid metal,‡ having the appearance of melt-

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Tyranny has invented this refinement in cruelty, to render it impossible for any thing to escape its restless vigilance.

"Thus in the dark Peruvian mine confin'd,
Lost to the cheerful commerce of mankind,
The unrelenting captive wastes his life away,
Forever exil'd from the realms of day;
With heart forlorn and sad, he pines in vain
For scenes he never shall possess again."—FALCONER

* Mercury is raised in such abundance in Spain, that in the year 1717 there remained above 1200 tons of it in the magazines at Almaden, after the necessary quantity had been exported to Peru for the use of the silver mines there.

The quick silver mines of Idria, a town in the circle of Lower Austria, have been wrought almost constantly for 300 years, and are thought upon an average to yield above 100 tons of quick silver annually. Bp. Watson.

† Mercury is found also in Hungary and China; it occurs most commonly in argillaceous schistus, flint stones, and sandstones. It is likewise found in several countries combined with silver, and frequently combined with sulphur. Native mercury is seen in globules, in some earths and stones of Mexico, and is collected from the clefts of the rocks there. Cinnabar, or sulphuret of mercury, is generally found also in those countries which produce the fluid metal. To extract the metal from the cinnabar, this ore is mixed with quicklime, and then submitted to heat. The lime combines with the sulphur, and the mercury, which sublimes from the mixed mass, is collected in receivers. An account of the whole process may be seen in the Memoirs of the French Academy for 1776. See also Note, page 292.

According to Proust, a small portion of mercury is united with all marine salt; and if his experiments be correct, all the muriatic acid of commerce must contain it in the state of corrosive sublimate, arising from the mercury naturally mixed with sea-salt. See Nicholson's Journal, vol. iii. 4to, 375.

‡ We see mercury always in a *fluid* state, because it is so very fusible that a small portion of caloric is able to keep it in

ver: in this state it is neither ductile nor able: very volatile when heated;* extremely ble; and is the heaviest of all the metals except platina and gold.† It readily combines with l of the other metals, and forms with them are called amalgams.‡

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of fluidity; but it is as perfectly opaque as other metals. tals require different portions of heat to fuse them. Lead with so little caloric, that when first melted the hand may ged in it without occasioning pain; whereas gold requires the heat of 32° of Wedgwood to melt it, and platina can- fused by the strongest heat of our best furnaces. Mer- when submitted to a sufficient degree of cold, is simi- appearance to other metals, and may be beaten into

It has been determined that 39 degrees below zero of heit's thermometer is the point at which the congelation cury takes place. At the poles quicksilver would proba- always solid.

e winter of 1799, Mr. Pepys froze 56 pounds of mercury

What effect has oxygen *upon mercury?*

Mercury does not combine with oxygen* in the ordinary temperature of the atmosphere, even when an extended surface is exposed; but if heated to about 600° of Fahrenheit, it gradually becomes oxidized. Acids are generally employed to oxidize it.†

What salts *are there of mercury?*

There is a great variety of mercurial salts; but the acetate, the sulphate, the nitrate, and the muriate of mercury are best known. The latter is found native in the Palatinate.‡

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he states at only 11.5, whereas the specific gravities of the metals from which it is formed are not less than 13—5 and 21. No one has hitherto given any satisfactory explanation of this curious circumstance.

* Mercury will not burn either in atmospheric air, in oxygen gas, or in oxymuriatic acid gas. The same may be said of gold and silver; which has induced Dr. Thomson to exclude these three metals from the class of combustibles. See his Essay on Combustion, in Nicholson's Journal.

† Mercury may readily be oxidized by dissolving it in nitric acid, and then the oxide may be separated by precipitating it from its solution by the addition of a pure alkali, or by exposing the solution to a proper degree of heat to expel the remaining acid.

The beautiful scarlet pigment called *vermilion* is prepared from mercury. It is the red sulphuretted oxide of mercury. Europe has hitherto been furnished with it by the Dutch manufacturers, and of greater beauty than any which has been procured from other markets; though it is said that even this article is inferior in splendour to that which is manufactured in China. What is imported from thence comes in small papers, and is nearly of the colour of fine lake.

‡ Several salts are formed by art with this metal for medicinal purposes; viz. *Keyser's pill*, which is an acetate of mercury; *Turbith mineral*, a sub-sulphate of mercury; *Red precipitate*, or oxide by means of the nitric acid; *Calomel*, or mild muriate of mercury; and *Corrosive sublimate*, which is an oxy-

Of what nature *is copper?*

Copper is of a red colour, very sonorous* and elastic,† and the most ductile of all the metals, except gold.

What is the effect of oxygen *upon copper?*

Copper will in some measure become oxidized by long exposure to atmospheric air, in which case its surface will be covered with a green oxide‡

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dip a feather into the acid, and wipe it over the polished blade of a knife; and if there be the smallest quantity of copper in it, the copper will be precipitated on the knife. A better mode of ascertaining the fact, perhaps, could not be devised.

* It is on account of this property that copper is chosen for making trumpets and other musical instruments.

† Copper, on account of its elasticity, is used by rope-dancers, &c. A wire $\frac{1}{10}$th of an inch diameter will support near 330lbs.

Copper will not burn so easily as iron; which is evident from its not striking fire by collision like iron. On this and other accounts this metal has been substituted for iron in the machinery which is employed in gunpowder mills.

Copper does not enter into combustion till it has acquired a heat more than sufficient to melt it. But if kept in a stream of oxygen gas, it will burn with a vivid blue flame.

Oxide of copper is soluble in ammonia, and precipitable from its solution by sulphuretted hydrogen.

‡ In domestic economy the necessity of keeping copper vessels always clean is generally acknowledged; but it may not perhaps be so generally known, that fat and oily substances, and vegetable acids, do not attack copper while *hot*; and, therefore, that if no liquor be ever suffered to grow *cold* in copper vessels, these metals may be used for every culinary purpose with perfect safety.

[illegible] the case of three men who died [illegible] suffering, in consequence of eating some [illegible] pickled in the brass coppers on board the Cyclops frigate. Thirty-one others became ill and were put upon [illegible], at the same time and from the same cause. [illegible] page 162.

Dr. [illegible] an account of a young lady who amused

similar to verdigris. It is susceptible of two degrees of oxidizement.* :

What salts *of copper are there?*

There are a great many salts of copper;† but those most used are the sulphate of copper,‡ ace

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herself while her hair was dressing, with eating samphire pickle impregnated with copper. She soon complained of pain in the stomach, and in five days vomiting commenced, which was incessant for two days. After this her stomach became prodigiously distended: and in nine days after eating the pickle, death relieved her from her sufferings. Medical Trans. vol. ii. &c.

* The first oxide of copper is red. It exists in nature in a mineral which is called the *ruby copper* ore; the perfect oxide is a grayish black.

† Roman vitriol, much used by dyers, and in many of the arts, is sulphate of copper. Fowling-pieces and tea-urns are browned by washing them with a solution of this salt. *Verdigris* is an acetate of copper. *Blue verditer*, much used in staining paper for hanging rooms, is a nitrate of copper combined with carbonate of lime. The beautiful grass-green colour of the shops called *mineral* green, is precipitated in a peculiar way from sulphate of copper, by means of caustic potash. The colour known by the name of *Scheele's* green is an arseniate of copper. The colour called *Brunswick* green is a triple salt, formed with potass, copper, and the tartaric acid.

‡ Sulphate of copper is frequently found in the streams of water in copper mines: these waters were suffered to run to waste, till an attention to chemical affinities taught the proprietors of the mines how to turn them to a good account. The quantity of salt which they contain is not sufficient to reimburse the expense of boiling it down to blue vitriol; but by throwing waste iron into these waters the salt becomes decomposed, and the copper is precipitated in a metallic form. This is owing to the sulphuric acid having a greater affinity for iron than it has for copper. In the isle of Anglesea this principle is turned to an advantageous account.

Bishop Watson relates, that the waters which issue from the copper mines in the county of Wicklow in Ireland are so impregnated with sulphate of copper, that one of the workmen having accidentally left an iron shovel in this water, he found it some weeks after, so incrusted with copper, that he imagined it was changed into copper. The proprietors of the mines, in pursuance of this hint, made proper receptacles for the water,

of copper;* nitrate, muriate, and arseniate of
er; and the tartrate of potass and copper.
les these, which are generally formed by art,
arbonate, the arseniate, the muriate, the phos-
, and the sulphate of copper are found in a
e† state.

hat are the uses of copper?

ne uses of this metal are too various to be
nerated. Besides its employment to make
els of capacity, and to sheathe the bottoms of
, it is alloyed with zinc to make brass,‡ it

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ow find these streams of as much consequence to them as
ines.

n account of the process of making verdigris at Mont-
may be seen in Mons. Pomet's History of Drugs, page
r in Annales de Chimie, tom. xxv. 305. The whole of

is combined with sulphuric acid to form Roman vitriol,* and its oxides are employed in enamel-painting, and the manufacture of several colours.

What is the origin *of iron?*

Iron is plentifully and universally diffused throughout nature, pervading almost every thing, and is the chief cause of colour in earths and stones. It may be detected in plants† and in animal fluids. It is found in great masses, and in various states, in the bowels of the earth in most parts of the world.‡

Egyptian women, whenever they went to their temples, carried one of these mirrors in their left hand. A process for separating zinc from brass will be found in Ann. de Chim. tom. xxxviii.

* In order to make Roman vitriol, plates of copper are heated red-hot in an oven, by which means they become quickly covered with a crust of oxide, which separates as the plates cool: this oxide is then boiled in sulphuric acid, and when it is dissolved and the solution is become of a proper strength, the whole is poured into leaden vessels to cool and crystallize.

Oxide of copper is used by the coloured glass-makers. It forms a beautiful *green* glass.

Mr. Sage has asserted that copper combined with phosphorus acquires the hardness of steel, is susceptible of the finest polish, and does not become altered in the air. See Phil. Mag. vol. xx. 159; but since the publication of the former editions of this work, an ingenious manufacturer assures me, that this combination is so very brittle and refractory, as to be unfit for any use in working.

Copper is used also in making prince's metal, gun-metal, bell-metal, tombac, and some other mixed metals.

† Iron has been found in metallic grains in strawberries. It is said that oak wood when dried contains one-twelfth of its weight of this metal.

‡ There is a great variety of iron ores (chiefly composed of the oxides of iron and clay,) which have different names given them by the workmen, and are of very different qualities; for which consult Bergman, Kirwan, and others.

Native metallic iron has been found in Siberia and in Peru,

hat is the nature *of iron?*

ure iron is soft and ductile,[a] and when dis-

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late of malleability, and yet in such enormous masses as eclude any supposition of their being the productions of Besides, they are found entirely insulated, and at great ces from any mountain, volcano, or bed of ore, from ce they might have been supposed to be derived. They similar in their composition to the meteoric stones, that lurray and some others are of opinion that they have the origin. La Place and Dr. Hutton suppose that these oric stones have been projected from a volcano in the

n the museum of the Academy of Sciences at Petersburg, ass of *native iron* twelve hundred pounds weight." In the vol. of the Phil Trans. p. 183, there is an account of an se mass of native iron 15 tons weight.

me of the French chemists are of opinion that iron owes its to decayed plants and animals.

n is found in greater abundance than any other metal In orthern parts of the world whole mountains are formed of re, and many of these ores are magnetic. Of the English the common Lancashire hematite produces the best iron

solved has a sweet and styptic taste, and emits a peculiar smell when rubbed strongly: it is attracted by the magnet, and has the property of becoming itself magnetic.* It is fused† with

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carry 450 pounds without breaking. A wire of tempered steel of the same size will carry near 900 pounds. Black.

Iron is of a livid blueish colour, very hard, and the most elastic of all the metals. Its specific gravity varies from 7.6 to 7.8.

Iron becomes soft by heat, and has the capability of being welded to another piece of iron, so as to form one entire mass, and this may be done without melting either of the pieces. No other metal possesses this singular property, except platina. Notwithstanding this, pure iron is nearly infusible. In order to effect the fusion of this metal, it is necessary to surround it with the fuel, and to urge the fire to the utmost possible pitch. Crude or pig iron is fused readily: hence, it may be cast into any form, and is employed in the fabrication of a vast variety of machinery and utensils.

* If a bar of iron be suspended for some time in a perpendicular position, it becomes magnetic. If friction be employed in a peculiar way, it quickly acquires strong magnetic powers. For particulars consult Cavallo's Elements of Natural Philosophy. The late Dr. Godwin Knight possessed a surprising skill in magnetism; being able, not only to communicate an extraordinary degree of attractive and repulsive virtue to his artificial magnets, but even to alter or reverse their poles at pleasure. This singular man refused every offer that was made to him for the discovery of his method, and, to the last, declared that the largest sum that could possibly be tendered, should not induce him to divulge it. Of course these curious and valuable secrets died with him.

The advantages which we derive from the magnetic property of iron are incalculable. To this astonishing property we are indebted for an instrument—the mariner's compass—by which man is enabled to traverse the ocean, to open a friendly or commercial intercourse with every quarter of the world, and to steer his course towards any particular country with the utmost accuracy and certainty.

"Tall navies *hence* their doubtful way explore,
And ev'ry product waft from ev'ry shore;
Hence meagre want expell'd, and sanguine strife,
For the mild charms of cultivated life." BLACKLOCK.

† Mr. Wedgwood fused some soft iron nails in a crucible at

What

Pure

gives fire by collision with

in the state in which it is pro-

from the ore?

employed in three states; viz. that

wrought iron,† and *steel*; each of

a different quality, and used for dif-

purposes.

What constitutes the difference in these three kinds of iron?

Cast iron is the metal in its first state, rendered fusible by the combination of carbon and oxy-

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the heat of 15½ of his scale. Sir George Mackenzie did not produce the same effect till his furnace acquired the temperature of 158°; cast iron melts at 130°.

Prussiate of potass is the usual test for iron. When added to a liquid which contains iron, it will cause a blue precipitate, if the iron has its full complement of oxygen; but if the iron is partially oxidized, the precipitate will be gray. Succinate of ammonia will precipitate oxide of iron from its solutions.

* To convert *cast* iron into *wrought* iron, the former is kept in a state of fusion for a considerable time, and, by repeated stirring in the furnace, the oxygen and carbon which it contains forms an union, and rise from the mass in the state of carbonic acid gas. As the carbon and oxygen thus go off, the iron becomes more infusible; it gets thick or stiff in the furnace; and the workmen know by this appearance that this is the time to remove it from the fire, and to submit it to the action of the hammer, or the regular pressure of large steel rollers, by which the remaining impurities are forced out, and the metal is rendered malleable, ductile, and totally infusible. In this state it is known in commerce by the name of bar iron. A considerable loss in weight, however, is sustained by this process; not only from the impurities, but from the surface of the iron oxidizing and falling off in scales while hammering.

† In purchasing wrought iron, the workmen distinguish two kinds which are both of very inferior value. They are called *hot-short* and *cold-short* iron. The former is a fusible metal, which possesses ductility when *cold*, but is so brittle when

gen.* *Wrought* iron differs from the former, in being deprived of this carbon and oxygen, by continued heat and repeated hammering, which render the metal malleable.† *Steel* is made of wrought iron, by various processes, whereby the metal resumes a small portion of carbon, and acquires a capacity of receiving different degrees of hardness.‡

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eated that it will not bear the stroke of the hammer. The use of this variety is not known. The latter kind is very malleable and ductile while hot, but the utensils made with it are as brittle as cast iron when cold. Such iron contains a portion of *phosphuret of iron*, which Bergman believed to be a new metal, and called it *siderite*.

* Cast iron which breaks of a *white* colour should be refused, as it contains a portion of phosphuret of iron.

† Though iron is deprived of part of its carbon and rendered malleable by hammering, a long continued hammering will deprive it of its malleability. Dr. Black was of opinion that this arises from the loss of a portion of its latent caloric, and that metals are malleable in proportion to the matter of heat which they contain in a latent state. Lectures, vol. i. 139.

‡ Steel, like cast iron, contains carbon; but it is divested of oxygen, which is always combined with the latter.

If a slender rod of wrought iron be plunged into cast iron in fusion, it will absorb part of the carbon, and become steel. What is called *case-hardening* is a conversion of the *surface* of the iron into steel.

Mr. Morveau exposed a diamond to intense heat, shut up in a small cavity in a piece of tough iron. When he opened the cavity he found the diamond entirely gone, and the iron around it converted into steel. Annales de Chimie, tom. xxxi. 328. This is one proof that the diamond is carbon, and shows that it is *pure* carbon which combines with iron to form steel, and not charcoal, which is generally an oxide of carbon. The peculiar hardness of steel is to be ascribed to its union with a portion of pure carbon or *diamond*.

It is no uncommon thing for jewellers to expose such diamonds as are foul, to a strong heat imbedded in charcoal to render them clear; but in this process great care is taken to have a sufficient quantity of charcoal to exclude the atmospheric air, otherwise the intense heat would produce combustion.

hat is the effect of oxygen *upon iron?*

on has such an affinity for oxygen, that it become oxidized merely by exposure to the The oxides of iron* are found in great

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el, by repeatedly heating and hammering it, may be con-
d into wrought iron.
steel instrument may be known from one of iron thus: If
p of nitric acid be let fall upon it, it will occasion a black
f it be steel, but will not have this effect if it be wrought
The blackness is owing to the acid oxidizing the carbon
e steel, and converting it into charcoal. For a method of
taining the quality of bar iron or steel, chemically, consult
lson's Philosophical Journal, 4to. vol. i. p. 470.
st steel is manufactured in some parts of this kingdom with
secrecy; but it is now known that it may be made merely
sing iron in an intense heat with carbonate of lime. Cast
contains more carbon, and is more fusible, than common

different tempers are given to all kinds of edge-tools, by

plenty ready formed in the bowels of the earth. This metal, like most others, is susceptible of various degrees of oxidizement.

What salts *of iron are there?*

The most useful salts of iron are those composed with the sulphuric, the nitric, the muriatic, and acetic acids; and these with some others are very essential to our manufactures.* The arseniate, sulphate, phosphate, chromate, and tungstate of iron have all been found native.†

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wards extracted from the mass by lixiviation and crystallization. This process is carried on upon a large scale at Deptford, near London, where the united acidifying powers of air and water are well exemplified.

According to Mr. Chenevix, there are four oxides of iron, the first or least degree of oxidizement being white, and progressively to green, black, and red, founded upon the different colours which minerals possess that contain iron. Others, however, think that this variety of colour results from the various combinations into which the two oxides of iron enter, difference of colour being a very uncertain mark of difference in the degree of metallic oxidizement.

* *Green vitriol*, which is of so much use in dyeing, in colouring hats, and in other manufactures, is a sulphate of iron formed, as has already been described, by the decomposition of martial pyrites. The nitrates, muriates, and acetates of iron are prepared by art for the use of the calico-printers, who consume great quantities of these salts in a state of solution.

† The native arseniate of iron is found in Cornwall; native sulphate of iron occurs frequently with pyrites; phosphate of iron ready formed is seen frequently in bogs,—it is called native Prussian blue; chromate of iron has been found in France and in Siberia; and tungstate of iron exists native in a mineral found in Britain and elsewhere, called wolfram. The sparry iron ore is a carbonate of iron.

Phosphate of iron has been very lately introduced as an important and efficacious application in cancerous complaints. See Medical and Physical Journal.

Carbonate of iron is commonly found in solution in chalybeate waters: such waters may be known by the dark orange-coloured film which generally appears upon their surface:

America,* and in the East Indies, but in England it is chiefly procured from Cornwall† and Devonshire.

What is the nature *of tin?*

Tin is a white metal, of little elasticity, and of but little ta[illegible] [illegible]e of the lightest‡ of the metals, a[illegible] [illegible]gly soft and ductile

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Tin is found o[illegible] mountains. Its ores occur most frequently i[illegible] in limestone. About 3000 tons weight of ti[illegible] nnually in Cornwall, two-fifths of which are use[illegible] to India by the East India Company; and in order to mak[illegible]m to take so large a quantity out of this market, they are allowed to have it at 70*s.* per cwt. See Additional Notes, No. 30.

* A very large quantity of tin is raised in South America, called Spanish tin. It is very pure, but not so neatly manufactured as the Cornish tin. A duty of 30*l.* per cent. prevents its being used in this country.

† According to Aristotle, the tin mines of Cornwall were known and worked in his time. Diodorus Siculus, who wrote about forty years before Christ, gives an account of the method of working these mines: he says that their produce was conveyed to Gaul, and from thence to different parts of Italy. The miners of Cornwall were so celebrated for their knowledge of working metals, that about the middle of the seventeenth century the renowned Becher, a physician of Spire, and tutor of Stahl, came over to this country on purpose to visit them; and it is reported of him that, when he had seen them, he exclaimed, that "he who was a *teacher* at home, was a *learner* when he came there."

‡ The specific gravity of tin is 7.291, or about 516 pounds to the cubic foot.

The purity of tin may be known by its specific gravity, its purity being in exact ratio with its levity; while gold, on the contrary, provided it be not alloyed with platina, is fine in proportion to its density.

Tin is much more combustible than many of the metals: it will burn in oxygen gas, before it acquires a heat sufficient to fuse it.

Tin is soluble in all the mineral acids. It may be precipitated from its solutions by potass; but an excess of

When converted into steel it is employed in various ways,* especially for edge-tools; all which are formed in part with this metal, from the ponderous pit-saw to the finest lancet.† Its oxides are used in painting, enamelling, dyeing, and in medicine.

Where is tin *procured?*‡

Tin is found in Germany, in Saxony, in South

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and whose effects are not to be feared. Indeed, its effects on the animal economy are evidently beneficial. For a detailed account of its various and important uses in medicine, consult Fourcroy's Elements, Thomson's edition, vol. ii. 466, and following pages.

The ancients had an idea that iron was poisonous, and that wounds made with iron instruments healed with difficulty. Hence, after the expulsion of the Tarquins, Porsenna stipulated with the Romans that they should not use iron except in agriculture.

* Good steel is much more ductile than iron, and hence the most minute instruments are generally made with it. A finer wire may be drawn from it than from any other metal.

† The excellence of edge-tools depends upon the temper given to them by heat. This requires great skill and peculiar management. A valuable report on the art of making fine cutlery may be seen in Nicholson's Journal, 4to. vol. iv. 127.

Sulphate of iron is not only used by the hatters and dyers, but also in making ink, in the manufacture of Prussian blue, in preparing leather, and in forming colcothar for painters. Colcothar is nothing more than sulphate of iron calcined to redness. It not only makes an useful pigment, but is employed in polishing different kinds of metals. It is from the iron which it contains that the piece of an old hat is useful for the same purpose. The oxide of iron imparts its colour to a great variety of natural substances. It is the cause of the redness of common bricks; it gives colour to the cornelian, the oriental ruby, the garnet, and other precious stones. With different proportions of oxygen it imparts other and different colours. Thus it gives the blue to the lapis lazuli, the yellow to the topaz, &c. See Additional Notes, No. 40.

‡ Tin must have been known very early, as it is mentioned in the books of Moses. The edge-tools of the ancients, and their coins, were made with mixtures of copper and this metal.

What are the uses *of tin?*

Tin is consumed in large quantities by the dyers;* it is used also for covering sheet-iron to prevent its rusting,† and in forming plumbers' solder, speculum metal, pewter, and some other alloys. Its oxides are used in polishing glass, in glazing some kinds of earthen-ware, and for various other purposes.‡

What is the use of tin to the dyers?

Tin is employed by the dyers to give a bright-

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* Tin is used to form boilers for dyers, worms for rectifiers' stills, and many other utensils employed in the arts.

† The consumption of tin for covering thin rolled iron, and forming what are improperly called sheets of tin, is very considerable: besides this, tin is used for coating the inside of iron and copper utensils, brass and iron pins, &c. For the method of doing this, consult Additional Notes, No. 30.

The use of tin was known to the Grecians. Homer mentions it in the Iliad. Pliny says, the Romans learnt the method of tinning their culinary vessels from the Gauls. They used tin also to alloy copper for making those elastic plates which they employed in shooting darts from their warlike machines.

Tin is employed to form bell-metal, bronze, brass for cannon, and a variety of other compounds. The addition of tin renders copper more fluid, and disposes it to assume all the impressions of the mould. It was probably with this view that it was used by the ancient Romans in their coinage. Many of the imperial *large brass*, as they are called, are found to consist of copper and tin alone. Coins also frequently occur which are undoubtedly antique, that contain a very large proportion of tin, made by the forgers, in the different reigns, in imitation of the silver currency. There are coins of Nero of a most debased and brittle brass.

‡ A combination of the white oxide of tin with sulphur by means of mercury, forms *aurum musivum* (mosaic gold,) an article used by artists to give a beautiful colour to bronze. I suspect that the change produced in tin by this process gave rise to the idea of the transmutation of metals. If the alchymists were acquainted with this compound substance, no wonder that they should indulge the hope of being able to form gold. An experimentalist without theory is the dupe of every illusion.

ness to cochineal, archil, and other articles used in forming reds and scarlets; and to precipitate the colouring matter of other dyes.* For these purposes it is previously dissolved in a peculiar kind of aqua-fortis, called *dyer's spirit.*

What is the nature of lead *?*

Lead is a heavy metal of the specific gravity of 11.35, of a pale, livid, white colour; slightly sonorous, has scarcely any taste, and emits a peculiar smell on friction. It has little elasticity, and yields readily to the hammer, being the softest of all metals. It generally contains a small portion of silver,† and sometimes mercury.

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* Several of the colouring substances which produced to the ancients only faint and fleeting colours, give us such as are brilliant and durable by the use of this metallic solution. A considerable degree of nicety and judgment is, however, requisite for its preparation. The difficulty is in a great measure owing to the nature of the acid that is used; as those makers of aqua-fortis who know but little of chemical affinities, or of the nature and operation of this invaluable mordant, often furnish the dyers with an article which is unfit for their use. Few arts have received such improvements from chemistry as the art of dyeing; for even cochineal gave but a dull kind of *crimson* till a chemist of the name of Kuster, who settled at Bow near London, about the middle of the sixteenth century, discovered the use of solution of tin, and the means of preparing with it and cochineal a durable and beautiful *scarlet.*

† Lead may be mixed with gold and silver in a moderate heat, but when the heat is much increased the lead rises to the surface combined with all heterogeneous matters. The art of refining the precious metals is built upon this property of lead.

Lead, when dissolved in acids, has the property of imparting a saccharine taste to substances with which it may be mixed. The ancients knew that this metal rendered harsh wine milder, but they did not suppose that it was poisonous. According to Pliny, the Greeks and Romans proved the quality of their wines by dipping a plate of lead in them. Beckman's History

Where is lead procured?

Lead ore is very abundant in Scotland, in the *western parts* of Northumberland and Durham,* in *Derbyshire*, and in many other parts of the *world.*†

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of Inventions, vol. i. 398, 400. I have a treatise on the management of wines, printed so lately as 1783, which directs the use of lead in order to preserve them from acidity. How much is the present age indebted to chemical science, which instructs us respecting the properties of different substances! Some of our wine-merchants, probably in consequence of this direction, may have contaminated their wines with lead, without suspecting that they were distributing a slow poison to their customers. For the effects of lead on the animal system consult a late work by Dr. Lambe, on the Nature of Spring water. See Additional Notes, No. 31.

Lead will not only correct the acidity of wines, but it will also take off the rancidity of oils. With this intention I have been informed it is often used to make inferior olive oil pass for good.

Vats of lead have been used in some cider countries, which have produced incalculable mischief. What is called the Devonshire colick is occasioned by this practice, and is identified, by its effects on the system, with the colick of the plumbers, the painters, and the white-lead-makers.

"Lead in its metallic state, like all the other metals, is probably inert: but it is so easily acted upon by the weakest acids and alkalies, that it cannot be taken even in this form without the most imminent danger." Johnstone on Poisons, 113.

Sir George Baker has carefully investigated the effects of lead on the animal economy, and in the first volume of the Medical Transactions has fully described the *peculiar kind* of colick produced by it.

* The lead found in these countries occurs on the estates of Colonel Beaumont, and those of the late Lord Derwentwater. These last were forfeited to Government, and are now in possession of Greenwich Hospital.

† Lead ore is generally found in veins, both in siliceous and calcareous rocks. Galena, or sulphuret of lead, is very common both in masses and crystallized. Lead is also found combined with silver, antimony, sulphur, and bismuth. Oxides of lead combined with various earths also occur in mining countries. Lead ochre is a native oxide of lead.

What is the effect of oxygen *upon lead?*

Like other metals, lead presents us with a variety of its oxides,* and according to the dose of oxygen, we have the gray, the white, the red, or the brown oxide† of this metal.

Lead was in common use among the ancients. The Romans sheathed the bottoms of their ships with this metal, fastened by nails made with bronze. During the first century, lead at Rome was twenty-four times as dear as it is now in Europe; whereas tin was only eight times its present price.

Lead, in the state of cerusse, was in great request among the Roman ladies as a cosmetic. Plautus introduces a waiting-woman refusing to give her mistress either cerusse or rouge, because, forsooth, in the true spirit of a flattering Abigail, she thought her quite handsome enough without them. Bishop Watson.

The lead ores which are found in the primitive slate mountains contain much silver, generally 8 or 9 per cent.

* When lead is melted in an iron ladle, a scum will quickly appear upon its surface: if this be removed, another will immediately succeed; and in this manner the whole of the lead may be converted into a gray pellicle, which is the *gray* oxide of lead. If this gray oxide be exposed to a low red heat in a reverberatory furnace, it will acquire a further dose of oxygen, and be converted into yellow massicot; and if the heat be continued, it will at length be changed to *red* oxide of lead.

† When nitric acid of the specific gravity 1.260 is poured upon the *red* oxide of lead, 185 parts of the oxide are dissolved; but 15 parts remain in the state of a deep brown, or brilliant flea-brown powder. This is the *brown* oxide of lead, containing 21 per cent. of oxygen.

Lead may be converted into an oxide by heating it in a situation where it can have free access of atmospheric air. All the oxides of lead may, however, be reduced to metallic lead by heating them with a mixture of tallow and charcoal, or any substance that will absorb the oxygen. This may readily be shown by placing a few grains of red lead upon a piece of charcoal, and fusing it with a blow-pipe. Even the oxide of lead which is combined with flint-glass, may be revived by melting the glass with any carbonaceous substance.

Fourcroy says that all the oxides of lead have the property of absorbing carbonic acid from the atmosphere; and that if an oxide of lead be required in a state of purity, it ought to be defended from the access of air.

hat salts *of lead are there?*

ne salts of lead are very numerous, perhaps l to the number of acids; but the muriate, ate, carbonate, and acetate of lead* are most known. The carbonate, murio-car- te, sulphate, phosphate, molybdate, arseniate chromate of lead are native productions.

hat are the uses *of lead?*

ead is employed to cover buildings, to form r-pipes, to make a great variety of vessels conomical and chemical purposes;† and in ng gold and silver.‡ Its oxides are used

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ccording to Mr. Hume, nitrate of lead, as a chemical test, l always be preferred to acetate of lead, as the last is so to give false results. Phil. Mag. vol. xx. page 160.

d forms an insoluble compound with sulphuric acid, and

for dyeing and calico-printing; in the manufactures of glass,* earthen-ware, and porcelain ;† and in the preparation of various pigments.

What is the nature of nickel?

NICKEL is a fine white metal, ductile and malleable, but of difficult fusion.‡ It is attracted§

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their evaporation during the cupellation; while it separates them from those metals which do not become oxidized by heat only.

* Lead is used in the finer kind of glass, in order to make it bear sudden changes of heat and cold better; also to give it a proper degree of weight, a susceptibility of its being cut without breaking, a greater power of refracting the rays of light, and a capacity to bear a higher polish.—Notwithstanding, lead is seldom used in plate or crown glass, as it always renders glass softer, and consequently more liable to be defaced by hard substances.

† The oxides of lead and of tin were employed by the ancient Romans in the manufacture of earthen-ware, &c.

The oxides of lead, dissolved in various menstrua, are used as embrocations, and for several other preparations, by the practitioners of medicine and surgery.

‡ M. Richter has lately been occupied in a series of experiments upon nickel. He has found that this metal in its pure state is very malleable, nearly as brilliant as silver, and more attractable by the loadstone than iron. It is generally combined with copper; but he has found a method of freeing it from that metal. He says that when pure it is not liable to be altered by the atmosphere; that it is perfectly ductile, and has great tenacity. Its specific gravity when forged is 8.666. Annales de Chimie, tom. liii. page 173.

§ Many chemists have imagined that nickel and cobalt are magnetic, only in consequence of a portion of iron which they contain; but in a paper in Nicholson's Journal, 8vo, vol. iii. 286, Mr. Chenevix has shown that these metals are really magnetic; and that, when they appear to be destitute of this property, it is owing to arsenic which is combined with them. Indeed, magnetic needles have lately been made with purified nickel, and have been esteemed more than those of steel, as being less liable to be affected by a damp atmosphere.

"So turns the needle to the pole it loves,
With quick librations trembling as it moves." DARWIN.

by the magnet, and has itself the property of attracting iron.*

Where, and in what state, is nickel found?

The ore of nickel is very similar to that of copper; it is procured from various parts of Germany, and is often found with cobalt; but the nickel of commerce is always impure.†

What is the effect of oxygen *upon nickel?*

If purified nickel be exposed to atmospheric air‡ in an intense heat, it is slowly oxidized, and then acquires an increase in weight of 33 *per* cent. We are acquainted with only one oxide of this metal.§

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* As the nickel of commerce always contains iron, this may disguise its properties, and prevent its nature being exactly known. This metal dissolves readily in several of the acids, and communicates to them a green colour; but sulphuric acid acts very slowly upon it, even with the assistance of heat. Nitric acid dissolves it more readily.

† The most abundant ore of this metal is a sulphuret of nickel, called *kupfernickel*, which is generally a compound of nickel, arsenic, and sulphuret of iron.

It is a curious circumstance, that all the specimens that have been examined of the stones which have been said to fall from the atmosphere contain iron alloyed with nickel. These stones, which have at different periods been seen to fall on every quarter of the earth, are supposed by many to be cast from a volcano in the moon. So lately as 1803 a shower of them fell in Normandy, which covered an extent of three quarters of a league long, and half a league broad. Several dissertations on this curious subject may be seen in the latter volumes of the Philosophical Magazine; Nicholson's Journal; and other periodical and scientific works.

‡ An oxide of nickel is more easily obtained by exposure to heat with nitre: it is of an apple-green colour. According to Thenard, another oxide of this metal may be obtained of a black colour, by exposing the green oxide to a red heat, or by treating it with oxygenized muriatic acid. Phil. Mag. vol. xx. p. 97.

§ Oxide of nickel is found in combination with some stones

What salts *of nickel are there?*

Numerous salts have been formed with nickel, but none of them have hitherto been brought into any use. A native arseniate of this metal has been found.*

What are the uses *of nickel?*

Nickel is employed in China in making *white* copper, which is a beautiful metallic compound; but it has not been much used elsewhere, although it may be had in considerable quantities.†

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this oxide may be dissolved in a solution of ammonia, and is not precipitated by sulphuretted hydrogen.

According to M. Richter, the oxides of *purified* nickel are of a much more lively green colour than the ordinary oxides; and their solution in ammonia is of a pale blue colour.

The oxide of nickel is said to afford the French manufacturers of porcelain a very delicate grass green; and, like other metallic colours, bears the intense heat of their ovens without injury. A hyacinthine colour may be given to flint glass by melting it with this oxide.

* For a description of this native salt, consult vol. ii. of Kirwan's Mineralogy.

† It is generally said that nickel has never been brought into use in England: but I have heard from Birmingham, that some of the manufacturers of that town combine it with iron, and thus use it with great advantage; and that others melt it with brass in such proportions as to form a very handsome compound metal, exceedingly useful for many purposes. The Chinese employ it also in conjunction with copper and zinc for making children's toys.

According to Proust, nickel, in a certain proportion, gives a degree of *whiteness* to iron, diminishes its disposition to rust, and adds to its ductility.

The valuable qualities which M. Richter has discovered in nickel, show that it might be applied to many important uses, particularly for surgical instruments, compass needles, and other such articles, as it is not liable to oxidize by the atmosphere. Should an easy method of working it ever be discovered, we may possibly find this to be better calculated for a variety of purposes than any other metal.

What is the nature of zinc ?

Zinc is a very combustible* metal, possessing but a small degree of malleability† and ductility, except under certain circumstances.‡ When broken, it appears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle, which, in consequence of its affinity for oxygen and carbonic acid, reflects various colours.

How is zinc *procured* ?

Zinc, generally called by our artists *spelter*, is

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* Zinc, if beaten out into thin leaves, will take fire from the flame of a common taper. It is the most combustible metal we have. It will decompose water without the assistance of heat. Next to manganese it has the strongest affinity for oxygen of all the metals. Its sp. gr. is 6.861.

‡ Messrs. Hobson and Sylvester, of Sheffield, have shown, that at a temperature between 210° and 300° of *Fahrenheit*, zinc is really a malleable metal; that it yields to the hammer, and, while kept at this temperature, may even be wire-drawn. They moreover say, that, after having been thus annealed and wrought, it continues soft, flexible, and extensible, and does not return to its partial brittleness, but may be bended and applied to many uses for which zinc has hitherto been thought unfit. If so, this is an important discovery; and in future there will be no impediment to its being formed into vessels of capacity, into utensils for various manufactories, sheathings for the bottoms of ships, and for other obvious applications.

Since the above was written, I have been informed that Mr. Phipson, an ingenious chemist of Birmingham, was acquainted with this property of zinc long before Messrs. Hobson and Sylvester took out their patent, and that he sent plates of this metal, which he had himself rendered malleable, several years ago to Dr. Priestley in America.

† The nature of zinc is such, that it seems to form the link between brittle and malleable metals. It is difficult to procure it in small particles, as the hammer flattens it instead of reducing it to powder. Macquer says, that, if it be heated very hot, it becomes brittle, and may then be pulverized.

not found native,* but, in England and elsewhere, is extracted from calamine and other ores, by distillation.†

What is the effect of oxygen *upon zinc?*

When zinc is heated it readily attracts oxygen, and at a white heat the absorption of oxygen, even in the common atmosphere, is so rapid and vio

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* Some mineralogists consider zinc to be the most abundant metal in nature, excepting iron. Calamine, or lapis calaminaris, is found both in masses and in a crystallized state, and is generally combined with a large portion of silex. Calamine is a *native oxide* of zinc, combined with carbonic acid. Zinc is found also in an ore called *blend*. In this state it is mineralized by sulphur. The miners call it Black Jack—a mineral employed till lately in Wales for mending the roads.

In China there is a great abundance of zinc: it is used in that country for current coin, and for that purpose is employed in the utmost purity. These coins have frequently Tartar characters on one side, and Chinese characters on the other. They have generally a square hole in the centre, that they may be carried on strings, and more readily counted.

† Metallic zinc is procured from calamine by distillation *per descensum*. The calamine is pounded, and with powdered charcoal put into large pots, which are placed in a furnace like a common oven. These pots have tubes fixed in their bottoms, which pass through the bottom of the furnace into a vessel of water. After the tops of the pots are covered, and rammed close with clay, a strong fire is made around them, so that the metallic zinc, being separated from the ore, and being of a volatile nature, is forced to rise to the upper entrance of the tubes, and thence passes downwards into the water.

In order to analyse the ores of zinc, it is necessary to operate upon them in retorts, and to collect the distilled metal in close receivers; for, if reduced in a common furnace, the greater part of the produce would be dissipated. The same attention is necessary when operating upon arsenic.

Zinc may be known by dissolving it in a mineral acid, and then adding ammonia, which precipitates it of a white colour, and redissolves it instantly. Sulphuretted hydrogen, added to a solution of this metal, produces a white and lasting precipitate.

What is the nature of zinc ?

Zinc is a very combustible* metal, possessing but a small degree of malleability† and ductility, except under certain circumstances.‡ When broken, it appears of a shining blueish white; and when exposed to the air, it becomes covered with a pellicle, which, in consequence of its affinity for oxygen and carbonic acid, reflects various colours.

How is zinc *procured ?*

Zinc, generally called by our artists *spelter*, is

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* Zinc, if beaten out into thin leaves, will take fire from the flame of a common taper. It is the most combustible metal we have. It will decompose water without the assistance of heat. Next to manganese it has the strongest affinity for oxygen of all the metals. Its sp. gr. is 6.861.

† Messrs. Hobson and Sylvester, of Sheffield, have shown, that at a temperature between 210° and 300° of Fahrenheit, zinc is really a malleable metal; that it yields to the hammer, and, while kept at this temperature, may even be wire-drawn. They moreover say, that, after having been thus annealed and wrought, it continues soft, flexible, and extensible, and does not return to its partial brittleness, but may be bended and applied to many uses for which zinc has hitherto been thought unfit. If so, this is an important discovery; and in future there will be no impediment to its being formed into vessels of capacity, into utensils for various manufactories, sheathings for the bottoms of ships, and for other obvious applications.

Since the above was written, I have been informed that Mr. Phipson, an ingenious chemist of Birmingham, was acquainted with this property of zinc long before Messrs. Hobson and Sylvester took out their patent, and that he sent plates of this metal, which he had himself rendered malleable, several years ago to Dr. Priestley in America.

‡ The nature of zinc is such, that it seems to form the link between brittle and malleable metals. It is difficult to procure it in small particles, as the hammer flattens it instead of reducing it to powder. Macquer says, that, if it be heated very hot, it becomes brittle, and may then be pulverized.

used in medicine: it is the base of white vitriol; and its carbonate or oxide may be advantageously substituted for white lead in house-painting.*

What is the nature of antimony?

Antimony† is a brilliant, brittle metal, of a dusky white colour, and is destitute of ductility. Though seemingly hard, it may be easily cut with a knife.‡

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previously roasted; it is then mixed with charcoal and grain copper, and put into large crucibles, which are kept for a considerable time in a heat that will not melt the copper; after a time, the heat is raised so as to fuse it, and the compound metal is then run into ingots. Brass is a valuable alloy on many accounts, especially the superior brightness of its colour, in its not being so liable to tarnish by exposure to the air as copper, and in its being more readily melted, and more malleable when cold. Sieves of extreme fineness are wove with brass wire, after the manner of cambric weaving, which could not possibly be made with copper wire.

* See Annales de Chimie, No. 103.

Zinc, in fine filings, is used to mix with gunpowder, to produce those brilliant stars and spangles which are seen in the best artificial fire-works. It is also one of the metals employed to form Galvanic batteries.

An amalgam of zinc is used to rub upon the cushions of electrical machines. It is very conveniently amalgamated, by melting it in a bowl of a tobacco-pipe, and pouring it while hot into the mercury. I have amalgamatized bismuth and other metals, but never found one of them to answer for electrical purposes equal to zinc, or an amalgam made with a mixture of tin and zinc.

† According to Bergman, the specific gravity of antimony is 6.86. If this metal be ground fine, and thrown into a dry glass jar filled with oxymuriatic acid, it will inflame immediately, and continue to burn with great rapidity and with a brilliant white flame. The combustion affords a beautiful spectacle. The product will be what is called *butter of antimony*. It also fulminates by percussion with oxymuriate of potash.

‡ Antimony may be known from bismuth thus:—Bismuth is very soluble in nitric acid, but antimony dissolves in it with difficulty.

that the oxide appears to sublime: hence its
e acquired the name of *flowers* of zinc. It
also be oxidized by acids. We are acquainted
only two oxides of this metal; viz. the yel-
and the white oxide.

hat salts *of zinc are there?*

great number of salts* have been formed with
metal; but the carbonate, the sulphate, and
y the acetate of zinc† are most known; the
first are found in a native state.

hat are the uses *of zinc?*

inc is combined with copper or tin, in various
ortions, which constitute some of the most
l compound metals or alloys;‡ it is also

Zinc has so great an affinity for oxygen, and its salts are so

lime and antimony,* and the tartrate of potass and antimony.† The first has been found native.

What are the uses of antimony?

Antimony is combined with some other metals in making printers' types, and specula for telescopes. Its oxides are employed in medicine,‡ and in colouring glass. In times of remote antiquity it was used by females as a black pigment, for staining the eye-lashes.

What is the nature§ of bismuth?

Bismuth is of a yellowish white colour, of a lamellated texture, and moderately hard, but not

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of algaroth, is made by merely dropping the solution into pure water. Muriate of antimony has been found native in Bohemia.

* The well-known medicine, called *James's powder*, is a phosphate of lime and antimony. It is a triple salt, in the form of a white powder. For a method of preparing it, consult Phil. Mag. vol. xi.

† *Emetic tartar* is a tartrate of potash and antimony, composed of about 56 parts tartrate of antimony, 36 tartrate of potass, and 8 of water.

‡ Perhaps we have no metal more valuable as a medicine than antimony, or one that is applied in such various ways. For particulars, consult the New Edinburgh Dispensatory, by Dr. Duncan, jun.

Kermes mineral, and what was called *golden sulphur* of antimony, are both made from the sulphuret of this metal, by means of potass. The first took its name from its resemblance in colour to the kermes insect, used in dyeing. The sulphuret, and some other preparations of antimony, are given to horses and cattle, more than any other medicines. They act as alteratives, and are generally to be depended upon for the certainty of their effects.

§ If water be added to a solution of bismuth in nitric acid, the oxide will be precipitated of a pure *white* colour; but if a little tincture of galls be poured into a similar solution, a *brown* precipitate will be produced. This is the distinctive characteristic of this metal.

ow is antimony *procured?*

ntimony is procured from an ore which is d chiefly in Hungary and Norway.*

What are the effects of oxygen *upon this metal?*

ntimony may be susceptible of several degrees xidizement; but at present we are acquainted only two oxides of this metal; the first con- $18\frac{1}{2}$, and the other 23, per cent. of oxygen.†

What salts *of antimony are there?*

any different salts have been formed with oxides of this metal; but those most known the muriate of antimony,‡ the phosphate of

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There are several ores of antimony, but the gray is the one which is found in sufficient quantity for the manufac- ; it is a sulphuret of antimony. This ore is purified by sure to a strong heat in a reverberatory furnace. By this

What salts *are there of bismuth?*

Several salts of bismuth have been formed, but their properties have not been much examined by chemists. The nitrate* and muriate of bismuth† are occasionally prepared, but no salts of this metal have been found in a native state.

What are the uses *of bismuth?*

Bismuth is used with other metals not only to form printers' types, but also to make pewter,‡ and for some other compounds. It remarkably contributes to the fusibility§ of some alloys:

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party had such an effect upon the disfigured fair one, that she was actually dying with apprehension, when the physician dispelled their fears, by informing his patient that nothing more was necessary than for her to wash her face, to abstain from the use of mineral cosmetics, and to trust in future to those charms which nature had bestowed upon her.

Some of the French chemists recommend the use of the oxides of bismuth for dyeing, to fix some particular colours. Pomatum prepared with the oxide of bismuth turns the hair black.

* Nitrate of bismuth does not dissolve in water like other metallic salts, but becomes decomposed, forming one of the most delicate white precipitates; hence, this metal is readily distinguished from most others. This precipitate, washed and dried, is what has been called *magistery* of bismuth, or pearl white.

† *Butter* of bismuth, as it was formerly called, is a muriate of this metal.

‡ The common mixture for *pewter* is 112 pounds of tin, 15 pounds of lead, and 6 pounds of brass; but many manufacturers use also bismuth and antimony to compose this metal. Bismuth is likewise generally mixed with tin for vessels of capacity, &c. as it gives to that metal a greater degree of brilliancy and hardness. From its property of rendering lead more fusible, it is too often employed with that metal to adulterate quicksilver.

§ If 8 parts of bismuth, 5 of lead, and 3 of tin be melted together, the mixed metal will fuse at a heat no greater than 212°. Tea-spoons made with this alloy are sold in London, to surprise those who are unacquainted with their nature. They have the

malleable. It is so brittle that it breaks readily under the hammer, and may be reduced even to powder.*

How is bismuth procured?

Bismuth is generally found with cobalt in the cobaltic ores of Saxony and England. Native bismuth and sulphuret of bismuth are also found on the continent, but this is not an abundant ore.

What is the effect of oxygen upon bismuth?

Bismuth is gradually oxidized by fusion in atmospheric air; and may be thus converted into the last two varieties of oxides.†

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* Bismuth has the singular property of *expanding* as it cools. Hence, probably, its use in the metallic composition for printing types; as from this expansive property are obtained the

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hence, it is employed to make solder. Bismuth is likewise given in medicine, though, now, very rarely.

What is the nature* *of arsenic?*

Arsenic is generally found in combination with acids,† sulphur, or oxygen.‡ When reduced to its pure metallic state, it is a friable, brilliant metal, of a blueish white colour, easily tarnishing, that is, oxidizing by exposure to the air.§ In all its states it is extremely poisonous.‖

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appearance of common tea-spoons, but melt as soon as they are put into hot tea. A composition of lead, zinc, and bismuth, in equal parts, will melt with so small a portion of caloric, that it may be kept in fusion upon *paper* over a lamp.

* Arsenic may be known by the smell of garlic, and by the white fumes which it exhales when thrown on a piece of red-hot coal. Its sp. gr. is 8.310.

† Nitrate of arsenic will precipitate the salts of copper of a beautiful green colour. This precipitate is exactly the same as the native arseniate of copper found in the mines of Cornwall.

‡ The oxides of arsenic in solution are discovered by sulphuretted hydrogen, which produces a yellow-coloured precipitate. This precipitate is the same as that beautiful ore called orpiment (sulphuret of arsenic.)

§ If arsenic, in its pure metallic state, be kept covered with alcohol, its metallic brilliancy will be preserved.

If metallic arsenic be previously inflamed in oxygen gas, it will burn till the whole is consumed. The combustion is very brilliant, and forms a striking experiment.

‖ Dr. Pearson has said, that white arsenic, in the quantity of *one-sixteenth* part of a grain, is as harmless as a glass of wine, and, in that dose, is a remedy for inveterate agues. See Dr. Pearson on Sulphate of Iron, &c. Phil. Magazine, vol. xxi. 56. But it is so poisonous that if one grain, in complete solution, were administered at one time, it might occasion death.

Whenever arsenic has been taken internally, by design or mistake, the best medicine is sulphuret of potash (liver of sulphur) dissolved in water. A few scruples should be dissolved in half a pint or a pint of water, and administered a little at a time as the patient can bear it.

Where is arsenic found?

Arsenic is found in Bohemia, Hungary, Saxony, and other places on the continent.* It is united with, and contaminates, many of our metallic ores in England.†

What is the effect of oxygen upon arsenic?

Arsenic has a great affinity for oxygen, of which it admits of various doses, till it becomes at last arsenic acid.‡

What salts *of arsenic are there?*

The salts which have been formed with this

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* The arsenic of commerce is prepared in Saxony in the operation of roasting the cobalt ores for the manufacture of zaffre. The reverberatory furnace in which the ores are roasted terminates in a long horizontal chimney: and in this chimney the arsenical vapours are condensed, forming a crust, which at stated times is cleared off by criminals, who are condemned to this work, for crimes for which they would otherwise have suffered death. White arsenic is prepared by mixing the common oxide with potash, and submitting it to sublimation. By this process the arsenic is separated, and sublimed, leaving its sulphur behind, united to the potash.

In analysing the ores of arsenic, or the ores of any of the metals whose oxides are volatile, the upper part of the crucibles should always be filled with charcoal: so that whatever is volatilized may be caught by the charcoal, and immediately reduced.

† Arsenic is frequently found in martial pyrites, and in copper ores. See Gellert's Metallurgic Chemistry, and Henkel's Pyritologia.

Lead when contaminated by arsenic, may be purified by melting it with a few iron filings. The iron combines with the arsenic, and these, being lighter than the lead, float on the surface, from which it may be readily skimmed off.

‡ Arsenic is capable of combining with so large a portion of oxygen as to become changed into a perfect acid. See p. 193. There are four other metals which are completely acidifiable; viz. chromium, molybdenum, tungsten, and columbium: there is, however, some doubt respecting the acidifiable nature of tungsten.

metal are few: though muriate of arsenic was made by the old chemists, and was known by the name of *butter* of arsenic. None of the salts of this metal are found native.*

What are the uses of arsenic?

Arsenic is used to whiten copper,† and enters into most compositions for the specula of reflecting telescopes, and for other optical purposes.‡ Its oxides are employed in many processes of the dyer;§ also as fluxes for glass,‖ and in several of

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* Though there are no native salts in which arsenic forms the base, yet we are acquainted with several in which it is combined as an acid; such are the arseniates of lime, copper, iron, &c.

† Copper alloyed with arsenic forms a malleable and flexible metal that takes a fine polish. On account of these properties, this mixed metal is frequently used in the arts, plated with silver.

‡ The use of arsenic, in making factitious metals for the specula of reflecting telescopes, may be seen in a long paper on that subject by the Rev. John Edwards of Ludlow, in the Nautical Almanac for 1787.

Arsenic is used in making small shot. The design of it is to render the lead more brittle, and better capable of granulating. See Additional Notes, No. 27.

It is curious that if arsenic be combined with the ductile metals, it renders them brittle; but if with platina and some other metals that are refractory in the fire, it makes such more fusible.

§ The white arsenic of commerce was formerly much employed in dyeing; but La Grange and M. Berthollet inform us that the foreign dyers have now discontinued the use of it for some time, being persuaded of its utter inutility in any of their processes.

‖ According to Loysel, arsenic is also useful in purifying flint glass when in fusion. If white arsenic be mixed with melted glass that still contains carbonaceous colouring matter, it instantly combines with the latter, and the whole is volatilized. *Art de la Verrerie.*

the arts. The sulphurets of arsenic form valuable pigments of different colours.*

What is the nature *of cobalt?*

COBALT is a whitish-gray, brittle metal, nearly resembling fine hardened steel.† It is difficult

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* Sulphuret of arsenic is much used in calico-printing, on account of its property of readily dissolving indigo.

Orpiment and realgar are both sulphurets of arsenic. Realgar is a dark orange or scarlet, the other a beautiful lemon colour. They are both much used in dyeing and calico-printing. The former has lately been found native in Cornwall. The pigment called *king's yellow* is made from this mineral. Beautiful shades of different colours may be given to valuable furs by arsenical solutions. So that the substance which is most injurious to the animal economy, appears to be endowed with properties for embellishing the works of creation, and is made to minister in various ways to our gratification, by imparting colour to other bodies. How diversified are the means which the Creator hath adopted for the promotion of these designs!

"Who, not content
With every food of life to nourish man,
By kind illusions of the wondering sense,
Has made all nature beauty to his eye,
Or music to his ear." AKENSIDE.

Arsenic is used in preparing the beautiful colour called *Scheele's green*. For the method of making this colour consult Scheele's Chemical Essays, Gren's Chemistry, and others.

Sulphuret of arsenic has lately been employed with success in destroying the intolerable fetor which sometimes attends cancerous complaints. The method is by fumigation, but extreme caution is necessary in the use of it.

The Chinese and other Orientals form *realgar*, sulphuret of arsenic, into medical cups, and use lemon juice that has stood some hours in them, by way of cathartic.

† According to Bergman, the specific gravity of cobalt is about 7.700; though Tennant makes it to be 8.538.

Solutions of cobalt give a *green* colour by evaporation and heat. This may be shown, by moistening a little paper with the solution, or writing with it on paper, and drying the paper by a gentle heat. The oxide of cobalt in ammonia forms a red solution.

nufactures of porcelain; for it not only produces a beautiful colour, but endures the intense heat of their furnaces without any deterioration.*

What is the nature of manganese?

MANGANESE is a brilliant metal,† of a dark gray colour, of considerable hardness, and diffi-

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the whole to a coarse powder. The same composition reduced to an impalpable powder forms the smalt, sold under the name of powder blue; which is now not only used by laundresses, but is made the basis of several pigments. It has also been much employed by paper-manufacturers to give a blue tinge to writing and printing papers. During the present very high price of smalts, indigo might be prepared, so as to be used with great advantage in this manufacture.

In the fifteenth century cobalt was employed to colour glass, and yet till lately but small quantities of it have been used. Formerly the miners threw it aside as useless. They considered it so troublesome when they found it among other ores, that a prayer was used in the German church that God would preserve miners from *cobalt*, and from *spirits*. Beckmann's History of Inventions, vol. ii. 363. Other ancient uses of this metal as a colour may be seen in the same work.

* The greatest consumption of cobalt is by the potters and porcelain manufacturers, some of whom make their own colour from foreign zaffre. But in Staffordshire there are several people who make an entire trade of preparing this colour for the earthen-ware manufacturers, and who conduct the process with great secrecy. The usual price of the prepared colour is two guineas the pound.

† The specific gravity of manganese has been estimated at 6.850 by Bergman, and at 7.00 by Hielm.

Manganese was first procured in its pure metallic form by Kaim and Gahn between 1770 and 1775. An account of the process may be seen in Sir Humphry Davy's Elements of Chem. Phil. part i. page 300.

The oxide of manganese is abundant and easily procured; but the pure metal can only be obtained by art, and requires to be carefully defended from oxygen, which it rapidly absorbs. In order to preserve specimens in a metallic state, it is necessary to varnish them, or keep them immersed in oil, or ardent spirits.

When manganese is employed in making oxymuriatic acid for medicine, the purest, such as that of Upton Pyne, should be used. That from Bristol and the Mendip hills generally contains lead.

cult fusibility. It is very brittle, and when in powder is attracted by the magnet.

Where is manganese found?

The manganese, which we use in this country, is obtained in the state of black oxide, from Somersetshire and Devon.* It also abounds in America, and various parts of the continent. Pure manganese is never found native.

What is the effect of oxygen *upon manganese?*

This metal becomes oxidized by mere exposure to the air, and is susceptible of at least three different degrees of oxidizement, forming the white, the red, or the black oxide of manganese.†

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* Manganese is found either in the state of an oxide or a salt. But the discovery of English mines of it is a new acquisition to this country, owing to the spirit of research which chemistry has given birth to. A carbonate of manganese is found native in Sweden and Norway.

Dr. William Dyce, of Aberdeen, has lately communicated to the Society for the Promotion of Arts, &c. the discovery of a mine of manganese in his vicinity, of great extent, and of very fine quality. The gold medal of the Society was awarded to him for this discovery. The present produce of the mine is 20 tons per week.

Professor Beattie of Aberdeen has also discovered manganese in his neighbourhood, upon the river Don, of good quality.

Scheele discovered manganese in the ashes of burnt vegetables.

Proust has lately announced the discovery of a *native sulphuret* of manganese.

† The methods of giving the different degrees of oxidizement to this metal may be seen in Dr. Thomson's Chemistry, vol. i. 243.

If one part of the black oxide of manganese, and three parts of nitrate of potass, be melted in a crucible till no more oxygen gas is disengaged, a greenish friable powder is obtained, called *mineral cameleon*, from its property of changing colour during its solution in water. If a small quantity of this powder be put into a glass of water, the solution is first *blue*; oxide of iron then separates, and by its *yellow* colour renders the fluid green; this

What salts *are there of manganese?*

A variety of salts have been made with the oxides of this metal; but this class of salts has not yet been rendered useful.* A carbonate of manganese is found native in Norway and Sweden.

What are the uses *of manganese?*

The oxides of manganese are used in bleaching,† in purifying glass,‡ and in glazing black

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subsiding, the blue re-appears; then, as the oxide of manganese absorbs oxygen from the atmosphere, it becomes reddish, brownish, and at last black. It then subsides, and leaves the fluid colourless. Parkinson. In forming this compound, care should be taken that no sulphur comes in contact with it; as the addition of a very small portion of sulphuret of potass would counteract its effects.

The *rubellite* and the *amethyst* owe their colours to the *red* oxide of manganese. A *violet* colour may be given to flint glass by melting it with a large portion of the *black* oxide of this metal.

* There is this peculiarity in the salts of manganese, that, when dissolved in water, the manganese cannot be precipitated from its solution, in a metallic state, by any of the other metals, because, compared with all others, this metal has a superior attraction for oxygen.

† Manganese is used by the bleachers in making the oxymuriatic acid, which has the property of destroying all colours.

‡ Its use in making white flint glass may be seen in Berthollet's Treatise on Dyeing, vol. i. 8. It was employed for this purpose more than two thousand years ago. The rationale of its operation has been admirably explained by Bergman. See first edition of Murray's Chemistry, vol. iii. p. 435.

Dr. Dyce has suggested, that manganese may be advantageously employed to separate the pure from the baser metals. An account of the process may be seen in one of the last volumes of the Transactions of the Society of Arts, &c.

According to Monsieur Gazeran, manganese forms a component part of steel, and ought to be added to iron for its formation; the best German steel being, according to him, composed of

Iron	97
Manganese	2
Carbon	1
	100

earthen-ware. The black oxide is also much used by chemists for producing oxygen gas, which, by the application of a red heat,* it yields in great abundance.

What is the nature of tungsten?

TUNGSTEN is a heavy metal, procured from a mineral found in Sweden, and from an ore called *wolfram*, found in Cornwall, Germany, &c.; but its properties are not much known, neither is it brought into any use here.† The same may be said of molybdenum,‡ uranium,§ titanium,‖ tel-

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* Black oxide of manganese contains 40 per cent. of oxygen It quickly gives out 10 or 12 per cent. of this oxygen by the application of a red heat, but the remaining portions cannot be separated by the most intense heat.

† Tungsten has been used in France for making vegetable lakes. Its sp. gr. is 17.60. Its oxide is insoluble in either of the three mineral acids; and in this property it seems to differ from all other metals. Though tungsten has been recommended as a proper basis for colours, it shows in some instances a strange fugacious disposition. Mr. Hume left a piece of zinc for some time in a little of the triple acidulous solution of this metal, generally called tungstic acid, and obtained a most brilliant blue solution: this he placed over the gentle heat of a lamp to evaporate, with a view to obtain a useful pigment; it soon, however, entirely lost its colour. Phil. Magazine, vol. xix. 29.

‡ Molybdenum was first procured in a metallic state by Hielm in the year 1782; it has been employed, I believe, in some processes of dyeing in Germany. As the ore may be had in great plenty, it will probably some time hence come into general use here. Its specific gravity is 8.61. At present it is not used in any of the arts. A method of procuring the metal from its ore is given by Sir Humphry Davy, Elem. of Chem. Phil. part i. page 459.

§ Uranium was discovered by Klaproth in 1789, in a mineral called pechblend; it has since been found, combined with carbonic acid, in the common green *mica*.

‖ Titanium was first noticed in the year 1781 by Mr. Macgregor, in a grayish black sand, found in the vale of Menachan in Cornwall; but it has since been discovered by Klaproth in several other minerals.

ım,* chromium,† columbium,‡ or tantalium,§ cerium.‖ It will therefore be proper to defer consideration of these metals till their properhave been further investigated.

laving gone through the greater part of this chapn metals, endeavour to recapitulate the general *erties of this class of bodies.*

he metals are simple substances,¶ distinguish- from all other bodies by their lustre, by their ıt specific gravity, by their perfect opacity, by their superior power of conducting electy.

What are the obvious advantages which we derive these bodies?

'he metals are the great agents by which we

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*Tellurium was discovered by Klaproth in the year 1798 in

are enabled to explore the bowels of the earth, and to examine the recesses of Nature; their uses are so multiplied, that they are become of the greatest importance in every occupation of life. They are the instruments of all our improvements, of civilization itself, and are even subservient in the progress of the human mind towards perfection.*

You can doubtless offer some reasons why one metal possesses such opposite and specific differences from another?†

This variety is not to be attributed to chance, but must certainly be the effect of consummate wisdom and contrivance.‡ These metals differ

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verulent nature of the metallic oxides. Their undecompounded nature was first suspected by Mayo.

* The metals are seldom afforded by Nature otherwise than in a state of great impurity. It is to the use of our reasoning faculty that we owe the possession of any of them in a state fit for use. If we consider for a moment what would be the situation of the world if society were deprived of this class of bodies, we should then have some idea of the obligations we owe to the sciences of metallurgy and chemistry.

> ——————" Serene philosophy,
> Effusive source of evidence and truth!
> Without thee, what were unenlighten'd man?
> A savage roaming through the woods and wilds,
> Rough clad, devoid of every finer art
> And elegance of life." THOMSON.

The best information respecting the analysis of metallic ores may be had from Klaproth's Essays, to which I refer the reader.

† Much information on the nature of many of the metals may be collected from Mr. Hatchett's valuable paper on gold, in the Philosophical Transactions for 1803.

‡ " That beautiful law of Nature, whereby the different unorganized productions are impressed with regular forms, doth not cease to exist even under the hands of man in his various

much from each other in their degrees of hard-ss, lustre, colour, elasticity, fusibility, weight, lleability, ductility, and tenacity, that Nature ms to have had in view all the necessities of n, in order that she might suit every possible pose his ingenuity can invent, or his wants re-re.

By what means are these bodies rendered so im-tant to us?

We not only receive this great variety from hand of Nature, but these metals are ren-ed infinitely valuable by various other pro-ties they possess. By their combustibility,*

---

eriments. He finds the metallic ores under determinate us, or geometrical figures of different kinds; and, when by

their solubility in fluids, their combinations with phosphorus, sulphur,* and carbon, and by their union with each other,† whereby compounds or alloys are formed, extremely useful in a variety of arts, manufactures, and other requisites of life.

By what other means does Nature render these bodies subservient to our wants, and capable of ministering to our comfort and gratification?

Nature has furnished us with acids, in which the most refractory metals may be dissolved‡ and purified, and thus rendered fit for a variety of purposes, to which they could not otherwise be

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tion, the *light* comes in part from the combustible, and not the whole of it, as has been imagined, from the atmospheric air. Light and heat attend other combinations as well as those of oxygen.

* All the metals except platina and gold will unite with sulphur by fusion. But the natural sulphurets contain more sulphur than the artificial ones; they must therefore have been formed by Nature by other means than those we employ to produce these compounds.

† Several of the metals have a very strong affinity for each other, as may be shown by direct experiment. Mercury will dissolve lead, bismuth, zinc, and other metals. If a piece of lead and a piece of bismuth, each alloyed with mercury, be melted together, they form when cold a solid metallic mass; but from their affinity for mercury they have acquired so much fusibility that they will melt by the heat of boiling water. See note, page 341.

‡ The alchemists were in search of an universal *solvent* of all metals; but, as Sir Humphry Davy has remarked, if such a solvent really existed, nothing would be so much dreaded by modern chemists. It would prevent the analysis of every mineral into which it entered, and would be like the fabled water of the Styx, which petrified every thing it touched. How different are the views of the scientific chemist from those of the ancient adepts, who concealed their knowledge with the greatest care, and who appeared to have had no other object but how to surprise an ignorant and credulous multitude!

applied. By combining the metals with oxygen* we can invest them with *new* properties, and are enabled to employ these to promote the progress of the fine arts, by imitating the masterpieces of creation in the production of artificial salts, spars, and gems, of every colour and of every shade.†

How does oxygen produce these changes in metals?

Different metals, by their union with oxygen, acquire different colours, and the same metal attains a different hue, according to the portion of oxygen combined with it;‡ so that this wonderful substance seems destined not only to render us the most important services, but to embellish the works of creation, by the beautiful tints which

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* This is exemplified in a striking manner by the metal called chrome. When acidified and combined with lead, the metallic salt that results is of a beautiful orange yellow; whereas chromat of mercury is of the colour of vermilion; chromat of silver, of a carmine red; chromat of zinc and bismuth, a bright yellow.

† If phosphoric acid be united with silex by fusion, artificial precious stones may be prepared with the compound, which may be coloured to imitate any particular kind, by one or other of the metallic oxides.

In making enamels and artificial gems, the processes of Kunkel may be depended upon more than those of any other writer. He was the superintendant of several foreign glass-houses.

‡ The oxide of iron is an eminent example of this change of colour. No less than seven distinct colours, besides a great variety of shades, are observed in minerals containing iron; and to the iron in most cases is the colour to be ascribed. See p. 10. —White in the sommite. Black in the obsidian. Green in the euclase. Blue in the lazulite. Red in the garnet and ruby. Yellow in the topaz. Brown in the tourmalin.

it imparts to almost all subjects, whether of the animal, vegetable, or mineral kingdom.*

You seem to think that the changes which metals undergo by their absorption of oxygen *are the most surprising phenomena of nature:—can you recollect some other properties of oxygen, to serve as a comparison, and to elucidate its importance?*

When I consider, in addition to the multiform effects of oxygen upon metals,† that no animal can exist, no acid can be formed,‡ no kind of

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* I would recommend to the preceptor the perusal of an interesting paper on oxygen, by Fourcroy, in one of the volumes of the Annales de Chimie. A more comprehensive idea of the nature and operation of this wonderful substance may be acquired by reading that essay, than from most other treatises on that subject.

† It is no unusual thing for chemistry to be called by its votaries a fascinating science. That it is the most useful of all sciences cannot be denied; nor can there be the least doubt but that it has a strong tendency to enchant those who devote their attention to it. It serves as a powerful stimulus to youth, as it occupies their time so satisfactorily to themselves, and renders all low and unworthy pursuits truly detestable. But amidst the great variety of subjects which this science embraces, the changes which the metals undergo, by their absorption of oxygen, are perhaps more eminently calculated than any other of its departments, to give a relish for chemical pursuits, and to engage the young mind in the unremitted examination of the works of creation.

> "The philosophic youth
> To NATURE's voice attends, from month to month,
> And day to day, through the revolving year;
> Admiring, sees her in her *every* shape;
> Feels all her sweet emotion at his heart;
> While TRUTH, divinely breaking on his mind,
> Elates his being, and unfolds his powers." THOMSON.

‡ From some *late* experiments it would appear that an acid may be formed without oxygen; but the exceptions will be so few, that the assertion in the text will, as a general rule, always remain true.

ides are formed, the chief of which are by the access of atmospheric air, by the decomposition of water, and by the decomposition of acids.

Will all metals become oxidized by exposure to the air?

No: gold, silver, and platina, cannot be oxidized, unless in a very high temperature; though iron,* copper, and lead, merely by long exposure to the air, will become oxidized in the coldest atmosphere. Manganese, by such exposure, will in a few hours be converted into a perfect oxide.

Are metals ever exposed to the air with the design of converting them into oxides?

The common red-lead of the shops, which is a true oxide of lead, is made by melting that metal in ovens so constructed as to have a free access of atmospheric air.†

How is it known that the change of common lead to red lead is caused by the absorption of oxygen?

This is known by the increase of weight which the metal acquires during the operation;‡ and to

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* Metals not only become oxidized by atmospheric air, but sometimes, by exposure to its action, pass from a lower to a higher degree of oxidizement. Thus, if a solution of the common sulphate of iron be exposed to the atmosphere, it acquires a further dose of oxygen, and by degrees a portion of the metal, in a higher state of oxidizement, is precipitated.

† Some of the metallic solutions cannot be formed but in contact with atmospheric air or oxygen. Thus, copper or lead, placed in acetic acid, and excluded from the air, does not form any solution; but if the mixture be exposed, oxygen is absorbed, and the solution takes place.

‡ The following account of the manufacture of red lead, from Watson's Chemical Essays, will be a satisfactory proof of this

confirm the fact, the oxide may be again reduced, and the original quantity of metal left unaltered.

Do all metals increase equally when converted into oxides?

No: each metal has its extremes, between which it absorbs oxygen in various proportions:* and one metal may not only have a greater or less capacity, but also a greater or less attraction for oxygen than another; so that one will often rob the other, thus reducing the oxide to its primitive metallic form.†

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doctrine. In the manufactories of red lead in Derbyshire, the melted lead is exposed to atmospheric air; the surface soon becomes covered with a dusky pellicle; this pellicle being removed, another is formed; and thus, by removing the pellicle as fast as it forms, the greater part of the lead is changed into a yellowish green powder. This powder is then ground very fine in a mill, and, when washed and properly dried, is thrown back into the furnace, and by constant stirring for 48 hours, so as to expose every part to the action of the air, it becomes red lead, and is taken out for use. Twenty cwt. of lead generally give 22 cwt of red lead; so that 2 cwt. of oxygen is absorbed from the atmosphere during the process.

* This may be shown by keeping a given weight of iron-wire red-hot for some time in the bowl of a common tobacco-pipe, and weighing the iron before and after it has been submitted to the experiment.

† Zinc, by its powerful attraction for oxygen, decomposes a great number of salts and metallic solutions, and precipitates the metal from them in a metallic form. This may be exemplified by the experiment of the metallic tree, which has been attributed to Dr. Black. For the method of conducting it, see the Chapter of Experiments, No. 123.

Sir Humphry Davy has found that whenever one metal precipitates another from its acid solution, the body that falls down is usually free both from acid and oxygen; and that the whole of the oxygen and the acid is transferred from one metal to the other. Davy's Chemical Philosophy, vol. i. page 121.

The pin-manufacturers whiten their pins on the same prin-

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‡ The following account of the manufacture of red lead, from Watson's Chemical Essays, will be a satisfactory proof of this

with the metal to form a metallic oxide,* while the hydrogen, the other ingredient of the water, escapes in the form of gas.

Is it known what proportion of oxygen each metal requires, in order to its being converted to an oxide?

Most of the metals are capable of combining with different proportions of oxygen, according to the mode by which they are oxidized.†

In what instances are acids used to oxidize metals?

Many instances of this mode of forming metallic oxides might be adduced: thus, common white lead is made by exposing sheet lead to the fumes of acetous acid;‡ and the oxide of tin,

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* See the account of an experiment, page 105, which explains the operation of metals in the decomposition of water.

† With respect to some metals, one dose of oxygen occasions the loss of their metallic splendour; a larger dose destroys that splendour entirely; and the proportion of oxygen may be increased so far as to give to the oxides an appearance altogether earthy. We have reason to believe that most of the metals are capable of indefinite degrees of oxidizement, producing oxides of various colours, and possessing very different properties.

In the oxidizement of metals by acids, though there be no oxygen gas sensibly present by which it is effected, oxygen exists in the acids, also in the water with which the acids are diluted; and the effect is owing to the passage of a portion of oxygen from one of these substances to the metal; and the increase in weight which the metal acquires, is always equal to the weight of the oxygen absorbed. Whenever a metallic oxide dissolves in an acid, it causes the acid properties to disappear exactly as if an alkali had been employed; and saturates corresponding quantities of the different acids. Berthollet.

‡ The manufacture of white lead is conducted in the following manner: A number of earthen crucibles, holding from three to six quarts each, and nearly filled with vinegar, are placed in

bmitting that metal to the action of the ni-
cid.*

at are the properties *of metallic oxides?*

ey are in general friable and pulverulent;
eavier than the primitive metal; and with
ifferent acids form metallic salts.†

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ls of tan: upon these crucibles thin sheets of lead, rolled
coils, are placed, one coil over each crucible. The heat
hed occasions the vinegar to rise in vapour, which at-
itself to the lead, and oxidizes its surface to a considera-
pth. At a certain time the oxide which has been thus
l is scraped off, and the coils of lead replaced; in this
r the operation is repeated, till the whole of the metal is
ed. This oxide, which contains a portion of carbonic
s afterwards *washed*, and ground for sale. See Additional
No. 28; also Mr. Hume's Observations, in the Medical
ysical Journal for March 1805.

he metallic oxides readily combine with alkalies, and
ome of the earths, similar to the acids. Hence originated
ms plumbate of potass, plumbate of lime, arseniate of

Is it necessary to oxidize the metals that are intended to be formed into metallic salts?

All metals are incapable of dissolving in acids, until they are combined with oxygen.* This is a fact of great importance to be remembered; it is a truth to which there is no exception.†

Is there any instance of the stronger acids being made use of by manufacturers to dissolve metals?

Yes; the manufacturers of sulphate of copper,

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* It is not only true that all metals must be oxidized before they can be dissolved in acids, but they must contain a certain proportion of oxygen, which proportion varies according to the nature of the metal to be dissolved, and the acid that is employed. On the other hand, if a metal has combined with more oxygen than the necessary proportion, it will precipitate itself from the acid, and be incapable of forming a salt. The dyers are often perplexed by the operation of this principle. In making their solutions of tin, if they add the tin to the acid too hastily, or in too large quantities, and the aqua-fortis be not exactly of the best kind for their purpose, the tin becomes, by the violent action of the acid, more oxidized than it ought to be, and precipitates itself instead of remaining in the solution. To guard against this, the workman generally adds a quantity of common salt, which will sometimes absorb the superabundant oxygen. In some other metallic solutions, such as that of the black oxide of manganese, &c. it is necessary to add a third substance, for the purpose of depriving the metallic oxide of part of its oxygen, in order to prevent a precipitation.

† It is imagined that metallic salts can be formed with the metal in certain states of oxidizement only. Thus the salts of iron have been supposed to consist of the metal in determinate degrees of oxidizement; one, the green sulphate, containing it at the *minimum*, the other, the red sulphate, at the *maximum*; and that between these there are no intermediate combinations. But Berthollet has remarked (see *Chemical Statics*,) that in the crystallization of sulphate of iron, the first crystals are nearly without colour: those which succeed in the subsequent crystallizations assume more and more colour, to a deep green; and at last there is a liquor not capable of crystallizing, and which contains the metal in the state of the highest oxidizement. This proves, says he, that some metallic salts

monly called makers of Roman vitriol, boil oxide of copper in strong sulphuric acid, and olve it by that operation.*

hat other instances are there of manufacturers g the mineral acids for dissolving metals?

lver is dissolved in nitrous acid, by the refiners, ie business of parting;† gold is dissolved in ni-nuriatic acid, for painting china; and the dyers large quantities of tin dissolved in a peculiar prepared for that purpose.‡

it possible to recover metals which have been dis-d in acids?

he attraction of the different metals for oxygen various, that several of them, when dissolved, be precipitated even in a metallic form, by addition of metals that have a greater affinity

What is the usual mode of reducing metallic oxides?

Charcoal is the agent usually employed, on account of its superior affinity for oxygen.*

Are you acquainted with any other agent which is equal to the de-oxidizement of a metal?

Yes: some of the metals have so slight an union

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oxygen, which the different metals possess, seems to be in the following order:—manganese, zinc, iron, tin, antimony, arsenic, nickel, cobalt, copper, bismuth, mercury, silver, gold, platina.

* The usual mode of procedure is to mix a quantity of charcoal with the metallic oxide, and subject the mixture to an intense heat in crucibles. The oxygen combines with the charcoal, and with a portion of caloric, and goes off in carbonic acid gas; the metal then falls to the bottom of the crucible, and runs into a solid mass.

The reduction of metallic oxides, by mixing them with charcoal powder, and submitting them to the action of fire, probably gave rise to the fable of the Phœnix, a favourite emblem with the old chemists:

"Whene'er Arabia's bird, by age oppress,
Consumes delighted on his spicy nest,
A filial phœnix from his ashes springs,
Crown'd with a star; on renovated wings
A-wends exulting from his funeral flame,
And soars and shines, another and the same." DARWIN

It is not a new idea that combustion does not destroy the matter on which it operates. I have seen an old engraving of sundry chemical apparatus, with a phœnix in the midst of its flames, with this superscription:

"Naturæ regna instar Phœnicis per ignem revivi-scunt."

Of all known substances, carbon and hydrogen have the strongest attraction for oxygen. This accounts for their efficiency in reducing the oxides of several of the metals. Recent muriatic acid has the property of partially deoxidizing some of the metallic oxides. It has a greater affinity for oxygen than any other acid.

Mrs. Fulhame has explained the operation of hydrogen in this process very satisfactorily. See her Essay on Combustion, printed for Johnson, 1794.

oxygen, that even light* will separate it, reduce the oxides to their original metallic .† Hydrogen gas and some other com- ds will effect the same purpose, when assisted eat.‡

hat oxides are there besides metallic oxides?

e are acquainted with an oxide of each of the le combustibles,§ sulphur, phosphorus, and ogen; with two oxides of carbon, the other le combustible; and with two of nitrogen.

hat is the origin of the oxide of sulphur?

his oxide is formed by keeping sulphur melted‖ ome time in an open vessel, whereby it absorbs en from the surrounding atmosphere.¶

Oxygen gas is composed of oxygen, caloric, and *light.*

What is the origin of the oxide of phosphorus?

If phosphorus be not preserved entirely from the access of atmospheric air, it soon becomes first white, and then of a dark brown colour, by its union with oxygen. In this state it is *oxide* of phosphorus.*

What is the nature of the oxide of hydrogen?

Hydrogen differs from the other three simple combustibles in being capable of combining only with one dose of oxygen, whereas *they* form acids as well as oxides. The combination of oxygen with hydrogen produces water.†

What is the nature of the oxides of carbon?

The first degree of oxidizement of carbon produces *carbonous* oxide, or common charcoal;‡ the next degree of oxidizement gives it a gaseous form, and produces *carbonic* oxide.

How is carbonic oxide prepared?

Carbonic oxide, which was one of the last discoveries of Dr. Priestley, is procured by heating

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* Phosphorus, when newly prepared, always contains some oxide of phosphorus mixed with it; but this may be easily separated by plunging the mass into water heated to about 100. The phosphorus melts, while the oxide remains unchanged, and swims upon the surface of the melted phosphorus.

† For the nature and properties of water, see Chapter iv. page 96.

‡ Common charcoal is composed of about 64 parts carbon, and 36 parts oxygen; but it generally contains also a small portion of hydrogen. For the properties of charcoal, consult Chapter ix. page 264 to 270. Though charcoal in general contains a large portion of oxygen, it has lately been ascertained that oxygen is not a *necessary* part of charcoal. See note §, page 264.

rcoal with metallic oxides or earthy carbon-
; by which means the charcoal absorbs suffi-
t oxygen to put it in the state of gas.

What is the difference in the composition of car-
c oxide *and carbonic* acid?

arbonic *oxide* contains 60, and carbonic *acid*
ber cent. of oxygen.*

What are the properties of carbonic oxide?

arbonic oxide, like most other gases, is invi-
e and elastic; its specific gravity is somewhat
than that of atmospheric air; it is highly
ibustible,† but it is a gas that will not itself
port combustion, neither is it fit for animal
piration.‡

What are the oxides of nitrogen?

he first degree of oxidizement produces *ni-*

posing crystals of nitrate of ammonia in a retort to the heat of a lamp,* by which means the ammoniacal salt is decomposed, and this gas evolved.

What are the properties of nitrous oxide?

This gas bears the nearest resemblance of any other to atmospheric air. It will support combustion even better than common air; it is respirable for a short time;† it is absorbed by water; and is capable of forming salts of a peculiar nature, by its combination with alkalies. Its

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called it *dephlogisticated* nitrous gas. For further information respecting its properties consult *Davy's Researches*. Sir Humphry Davy has analysed it with great care, and pointed out its nature and properties.

* The heat should not be less than 400°, nor above 460°. One pound of nitrate of ammonia, well decomposed, will produce not more than four cubic feet of gas, or about 3½ gallons wine measure. Its specific gravity, according to Sir Humphry Davy, is to that of hydrogen gas nearly as 21 to 1. Ten cubical inches of it weigh about 48 grains.

Nitrous oxide, or the gaseous oxide of nitrogen, as it is sometimes called, is composed of 63 parts nitrogen, and 37 oxygen, by weight. Nitric oxide is formed with 44 parts nitrogen, and 56 parts oxygen.

† Persons who have inhaled this gas have felt sensations similar to those produced by intoxication. Its effects on some people are truly ludicrous, producing involuntary muscular motion, and a propensity to leaping and running; on others, involuntary fits of laughter; and in all, high spirits, and the most exquisitely pleasurable sensations, without any subsequent feelings of debility. When Mr. Robert Southey, the poet, inhaled it, he declared that it produced in him sensations perfectly new and delightful: and for several hours afterwards he imagined that his taste and smell were more acute than usual. In a poetical rhapsody, he remarked, that he supposed the atmosphere of the highest of all possible heavens must be composed of this gas. See Davy's Researches, and Nicholson's Journal, vol. iii. 4to, 446.

From its highly stimulant powers, this gas has been applied with advantage to the treatment of several diseases of debility, but I question whether it be more serviceable than pure oxygen gas diluted with atmospheric air.

ific gravity is much greater than that of com- air.

What is the origin of nitric *oxide; and how is it ured?*

itric oxide, or nitrous gas, as it has usually called, was also discovered by Dr. Priestley, ng some of his first experiments on air.* It is ured by digesting copper or mercury in diluted us acid, and collecting the gas which rises ng the solution.

What are the properties of nitric oxide?

itric oxide is an invisible gas, which assumes range colour whenever it comes in contact atmospheric, or any other air that contains en.† It produces suffocation in those ani- who attempt to breathe it, though some

substances will burn in it.* Its specific gravity is somewhat more than that of common air.

What compounds are formed by means of nitric oxide?

Nitric oxide gas, when mixed with oxygen gas, forms nitric *acid.* The aqua-fortis of commerce owes its colour to this gas.

What other oxides are you acquainted with?

The red colour of the blood is occasioned by an oxide of iron; sugar and indigo are vegetable oxides, and common soap owes its perfection to the absorption of oxygen.†

Are all vegetable and animal compounds thus improved by their combination with oxygen?

No: butter, dried salt meats, and most of the oils‡ become rancid by absorbing oxygen from

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* If phosphorus be previously inflamed, it will continue to burn in this gas with as much splendour as in oxygen gas.

Dr. Priestley found by experiment, that 100 measures of nitric acid, of a moderate strength, absorbed in two days 90 of nitrous gas: that when about 7 parts were absorbed, the acid assumed an orange colour, when 18 parts were absorbed a green colour, and when the 90 were combined it became red and fuming.

According to Sir Humphry Davy, the specific gravity of nitrous gas is to that of hydrogen as 14 to 1: 100 cubical inches of it weigh 32 grains

† In the essay prefixed to the first edition of the Chemical Catechism, page 19, I suggested to the manufacturers of soap an advantage that would arise from properly oxidizing the soap while boiling: the *late* experiments of some French chemists have established the truth of this theory, and demonstrated that this curious compound of oil and alkali is indebted entirely to oxygen for its consistence.

‡ Seed oils are sometimes oxidized artificially for the purposes of painting. Linseed oil is thus boiled with the red oxide of lead. In this operation the oxygen of the metal combines with

atmosphere;* so that oxygen not only performs
is an infinite number of valuable and important
es, but appears to be one of the grand agents
ecomposition and destruction.†

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il, imparting to it the property of drying quickly. Oil thus
ired is called *drying* oil.

All the oxides with which we are acquainted may be thus
ed. I. That arising from the combustion of hydrogen, by
h water, the oxide of hydrogen, is formed. II. Metallic
es. III. Acidifiable oxides; or such as by an addition of
en pass from the state of oxides to that of acids. The ox-
of phosphorus, sulphur and nitrogen, with four of the me-
oxides, admit of this change. IV. Various combinations
rbon and hydrogen in the animal and vegetable kingdoms.
is class common charcoal, oils, gums, resins, wax, sugar,
, soap, &c. belong.

All organized beings, whether vegetable or animal, possess
naterials of which they are composed only for a limited
life itself is a boon which is only *lent*, to serve the pur-
of infinite beneficence. At the proper period *oxygen*, or
other powerful agent, effects the decomposition of the cu-

CHAPTER XII.

OF COMBUSTION.

WHAT is combustion?

Combustion* is a process by which certain substances decompose oxygen gas, absorb its base,† and suffer its caloric to escape in the state of sensible heat.

Are all substances capable of being burnt?

No: some substances are combustible,‡ others incombustible.

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* Lavoisier and other French writers defined combustion to be the combination of any body with oxygen. This definition, however, has very properly been objected to; for there are many instances of oxygen combining with a body without producing combustion. Indeed, this union is sometimes effected when no combustion can possibly take place. Oxygen often combines with bodies without any sensible extrication of heat or light; but we never, in common language, give the name of combustion to any operation in which heat and light are not liberated.

† To render the explanation of this phenomenon more perspicuous, it may be said that oxygen exists in the state of gas in atmospheric air; that when a combustible is heated to a certain degree, it possesses such an attraction for oxygen, that it absorbs it from the air, and fixes it in a solid form; while the light and caloric, the solvents which gave the oxygen its aëriform shape, escape and diffuse themselves among the surrounding bodies. See Additional Notes, No. 36 and 38.

‡ The term *combustible* is applied to every body that is capable of being burnt in atmospheric air, or in oxygen gas, and, consequently, of uniting with oxygen.

How are combustible bodies classed by chemists?

nto simple combustibles, compound combus-
es, and combustible oxides.*

What do you mean by SIMPLE *combustibles?*

Those combustible substances that have resisted
y attempt to decompose them, are called sim-
combustibles.†

Endeavour to enumerate the simple combustibles.

The simple combustibles with which we are ac-
inted are hydrogen, sulphur, phosphorus,‡ car-
, and all the metals,§ except gold, silver, and
cury.

The combustible oxides consist of combinations of the
ustible bodies, which have not undergone combustion, or
compounds, with oxygen. This class of bodies is very
rous, as it includes the greater part of animal and vege-

What are COMPOUND *combustibles?*

Compound combustibles are all such as are formed by the union of two or more of the simple combustibles.* Common coal is an instance of this combination.†

What substances are there which are incombustible?

We are acquainted with three incombustible substances; viz. nitrogen,‡ the three alkalies, and the nine earths.§

What is the nature *of combustion?*‖

Combustion appears to be a double decompo-

The wire will take fire from the cotton, and burn with great brilliancy, throwing out very vivid sparks in all directions. During the combustion the iron combines with the oxygen in the jar, and is converted into an oxide, with an augmentation in weight of 35 per cent." Mr Accum says, that a thick piece of iron or steel, such as a file, may be burned in oxygen gas, if it be made very sharp pointed, and a small piece of wood be stuck upon its extremity, and set fire to previous to its being immersed in the gas. The method of suspending the metal in the jar may be seen in plate 4, fig. 17, of Lavoisier's Elements of Chemistry.

* These compound combustibles are arranged by Dr. Thomson under the two following heads. 1st, sulphurets; 2d, phosphurets; 3d, carburets; 4th, alloys; 5th, sulphuretted, phosphuretted, and carburetted oxides.

† Hydrogen and carbon, intimately united in the capillary tubes of vegetables, form bitumens, oils, and resins, which are compound combustibles. See Additional Notes, No. 39.

‡ Perhaps nitrogen might be called a *combustible* body, as by means of electricity it combines with the base of oxygen gas, and forms nitrous acid.

§ Some of the alkalies and earths possess certain properties in common with combustibles, and are capable of exhibiting phenomena somewhat analogous to combustion. These have been described under the title of *semi-combustion*; but for particulars I must refer the reader to Dr. Thomson's Theory of Combustion, in Nicholson's Journal for 1802.

‖ To the old chemists the process of combustion was quite

What is it that imparts to these various bodies the peculiar property of supporting combustion?

The principle common to all these substances is OXYGEN: it is therefore to oxygen alone* that they are indebted for this property.

Is it known how oxygen supports combustion?

The agency of oxygen in combustion is attributable to its affinity† for combustible bodies. For, whenever such bodies are ignited in circum-

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It is well known that water in many cases promotes and accelerates combustion. It appears that the ancients were acquainted with this property of water: hence the invention of the wedge-like, which was much in use formerly. Dr. Plott, in page 181 of his History of Staffordshire, mentions a curious instance of the employment of this instrument. He says that towards the autumn of [illegible] brought by his tenants to [illegible] about New Year-tide they [illegible] and the fire in the hall of the Lord of Hilton, while [illegible] of Hilton [illegible] figure having the [illegible] an oblong, blows the [illegible] (a very grotesque figure [illegible] at Hilton, [illegible] shell; and a drawing [illegible] in the [illegible] of Plott's Staffordshire. In [illegible] the Basingstoke [illegible] an antiquity of great antiquity was found, this was also of [illegible] contrived that the heat [illegible] from its [illegible] Heathen priesthood employed this [illegible] in working [illegible]. Some of the ancient Saxon and German idol- [illegible] this connection.

[illegible] the caloric which is liberated during [illegible] to suppose that all the supporters [illegible] oxygen, a [illegible] [illegible] [illegible]

stances favourable to combustion, they absorb oxygen from the air, or other contiguous substances, till the combustible is converted to an incombustible body.

From whence proceeds the heat which we observe during combustion?

In general the heat produced by combustion* arises from the oxygen gas of the atmosphere: for, as the oxygen combines with the combustible body, it disengages the caloric which it held when in the state of atmospheric air.

Can you explain this operation with more precision?

The act of combustion effects a real analysis of atmospheric air: for while the oxygen combines with the combustible, the caloric, in the form of sensible heat, is thrown off in every direction.†

Does this account for the long continued heat which we experience in every common combustion?

Whenever we burn a combustible body in order to procure heat, a continued stream of at

* Though every case of combustion requires that heat should be evolved, yet this process proceeds very differently in different circumstances. Hence the terms *ignition*, *inflammation*, *detonation*, &c.

† The rapid combustion that is occasioned by inflammable combustible substances, mixed with hyper-oxymuriate of potass, is owing to the large quantity of oxygen contained in this singular salt, and which it holds by a very weak affinity: and also to a large portion of caloric which this curious preparation contains in union with its oxygen, and which is evolved while its oxygen enters into combination with the combustible. See note † page 329.

mospheric air flows towards the fire-place* to occupy the vacancy left by the air that has undergone decomposition, and which in its turn becomes decomposed also.† Hence a supply of caloric is furnished, without intermission, till the whole of the combustible is saturated with oxygen.

What other effects are produced by combustion?

As the combustible burns, LIGHT is disengaged; and the more subtile parts of the combustible now converted by caloric into gas, are dissipated in that state.‡ When the combustion is over,

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* On some parts of the continent rooms are warmed by stoves that have ash-pits without; so that the combustion is kept up by air which has no connexion with the air of the room; consequently there is no current, nor is the air of the room contaminated; and the persons who occupy them are not subject to the inconvenience of those cold draughts of air which render some of our rooms that have large fire-places dangerous and unhealthy.

† Upon this principle, that a current of air hastens combustion, the Argand's lamp is constructed; for, in consequence of this perpetual supply of oxygen, the air is renewed every moment, and produces heat sufficient to burn the smoke as it is formed. The smoke which arises from a common fire is chiefly water in the state of vapour, with a mixture of carburetted hydrogen and bituminous substances; part of the water comes from the moisture of the fuel; the other part is formed during combustion, by the union of the hydrogen of the combustible with the oxygen of the atmosphere. What takes place in a common fire would furnish an intelligent parent or preceptor with matter for several interesting conversations, which could not fail to rouse the curiosity and contemplation of the pupil. See Additional Notes, No. 16 and No. 38.

‡ Part of the caloric which is furnished by the supporters of combustion, generally combines with a part of the combustible, and converts it into gas.

"Thus heat from chymic dissolution springs,
And gives to matter its eccentric wings;
With strong repulsion parts the exploding mass,
Melts into lymph, or kindles into gas." DARWIN.

nothing remains but the earthy parts of the combustible, and that portion which is converted to an oxide or an acid by the process.*

From whence proceeds the light which you say is disengaged during combustion?

It is now generally supposed that the light and flame which appear during this process proceed from the combustible body,† though some che-

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* The product of combustion is always either an *oxide* or an *acid*, or both, except when the new metals potassium or sodium are ignited, and then an alkali is the product. But indeed all kalies are now proved to be metallic oxides.

† If the light arose from the decomposition of oxygen gas, those combustibles which absorb most oxygen would give out most light; but this is not the case. *Pure* hydrogen in burning combines with more oxygen than any other body, and gives out more heat, yet the light is barely perceptible. Several instances might be adduced, in which the quantity of oxygen combining with the combustible, during this process, is greatest where the light is smallest.

Count Rumford has lately demonstrated that the light given out by a combustible body is in proportion to the elevation of temperature; in conformity to which he has constructed lamps with many wicks, so placed as to communicate heat to each other; and these lamps burn with much more brilliancy, and afford much more light, than the same number of wicks would give if placed in separate lamps.

The existence of light, as a constituent part of combustible bodies, seems to have been proved by the experiments of Deiman, Paets, and others. These chemists exposed a mixture of sulphur and zinc to a high temperature, without any substance being present from which they could derive oxygen. At the instant when the sulphur and zinc formed a *sulphuret*, there was a vivid emission of light; and when the materials were examined, it was found that no oxidizement had taken place. On this subject see Mr. Portal's remarks, Phil. Mag. vol. xv. p. 207. and Thomson's Chemistry, vol. i. 190. See also Note, page 354 of this volume.

"That a great part of the light comes from the combustible, is evident from the colour of the light generally varying according to the nature of the combustible. Carbonic acid burns with a blue flame, carburetted hydrogen with a white, charcoal

s imagine that the light comes in part from the
omposition of atmospheric air.*

Vhat is the origin *of light?*

ight, which is an extremely attenuated fluid
ier, is constantly transmitted from the sun to
earth.† It is also found combined with several
estrial substances.‡

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red, and sulphur with blue or violet." That lime contains
is well known. If quick-lime be slaked in the dark, the
ation of light will be very evident. See Additional Notes,
0; also note,† page 263.

The following fact seems to prove that atmospheric air con-
light. Some time ago a soldier in the French army found
heat was produced by the condensation of the air in an air-
The experiment was repeated before the National Insti-
and proved satisfactory. If the air be very rapidly com-
ed, heat is disengaged by the first stroke of the piston,
ient to set fire to a piece of fungus match placed within
umn; and if the end of the column be furnished with a glass

What is the nature *of light?*

Light is a peculiar substance, the nature of which is little understood,* but it possesses several very singular and striking properties.†

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this subject consult Dr. Hulme's paper in the Philosophical Transactions for 1800 and 1801: Dr. Herschel's paper in the former of these volumes, and Dr. Wollaston's in the volume for 1802; all which are extremely interesting. See also Dr. Henry's observations in the fifth volume of the Manchester Memoirs. From the following beautiful apostrophe to Light, by Milton, there is some reason to imagine, that even in his time some idea was entertained of light being latent in bodies:

"Hail, holy light! offspring of Heaven first born,
Or of th' Eternal co-eternal beam,
Bright effluence of bright essence increate.—
Thy fountain who shall tell? Before the sun,
Before the heavens thou wert; and at the voice
Of God, as with a mantle, didst invest
The rising world of waters dark and deep."

* Sir Isaac Newton described Light to be a substance consisting of small particles, constantly separating from luminous bodies, moving in straight lines, and rendering bodies luminous by passing from them and entering the eye. Those who wish to become further acquainted with all the known properties of light, such as the refraction, reflection, inflection, &c. of its rays, may consult Newton's Optics, Fourcroy's System of Chemical Knowledge, and the several papers by Herschel and Count Rumford, in the Philosophical Transactions.

† Light is decomposable into seven distinct rays of different colours. Some bodies absorb one coloured ray, others another, while they reflect the rest. This is the cause of colour in bodies. A red body, for instance, reflects the red rays, and absorbs the rest. A white body reflects all the rays, and absorbs none; while a black body, on the contrary, absorbs all the rays, and reflects none. Dr. Paley has remarked, "that if light had been made by a common artist it would have been of one uniform colour; whereas, by its present composition, we have that variety of colours which is of such infinite use to us for the distinguishing of objects; which adds so much to the

he presence of atmospheric air necessary to com-
n?

mbustion cannot take place in a vacuum; mbustible body can burn without atmospheric r at least without *oxygen*, which is a compo- part of the atmosphere.*

what do combustible bodies differ from each
?

mbustible bodies differ from each other prin-

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of the earth; and gently augments the stock of our inno- leasures."

"Nature's resplendent robe!
Without whose vesting beauty all were wrapt
In unessential gloom."

it has a great effect on vegetation. See note *, page 282.

cipally in the rapidity with which they absorb oxygen, and in the proportion of it which they can take up,* to form the new compound.

What is the effect of these properties, in the act of combustion?

The greater the quantity of oxygen gas which any combustible body is capable of decomposing, the greater will be the degree of heat that is produced by the combustion.

How is it known that oxygen unites with the combustible body in the act of burning?

If a combustible substance be burnt in a sufficient quantity of vital air in a close vessel, and the product preserved, the whole will be found to be increased in weight† exactly in proportion to the oxygen gas consumed, and the combustible body will then have become incombustible.‡

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* Almost all the simple substances are capable of combining with various doses of oxygen. Thus sulphur forms oxide of sulphur, sulphurous acid, and sulphuric acid; phosphorus forms oxide of phosphorus, phosphorous acid, and phosphoric acid; carbon also unites with different portions of oxygen, and forms carbonous oxide, carbonic oxide, and carbonic acid. When either of these simple combustibles is united to any other, or to either of the alkalies, earths, or metals, the combinations are known by names ending in *uret*, as sulphuret of potass, phosphuret of lime, carburet of iron, &c.

† Phosphorus is an eminent instance of this increase by combustion. If an ounce of phosphorus be properly inflamed, it will produce more than two ounces of phosphoric acid; the increase in weight arises from its absorption of oxygen.

‡ A series of curious experiments of this kind may be seen in Lavoisier's Chemical Elements, fourth edition, 135, and following pages.

at is the cause of a body becoming thus in-
stible?

hen a body is fully burnt it is saturated with
en; at least as far as combustion can saturate
therefore, cannot combine with any more:
ome bodies may be rendered combustible
by depriving them of the oxygen which
absorbed in their former combustion.*

the decomposition of atmospheric air by com-
n, what becomes of the nitrogen gas?

the oxygen becomes fixed in the combus-
body, its caloric is disengaged, a part of which
ines with the nitrogen, and carries it off in the
of rarefied nitrogen gas.

hat chemical name is given to burnt bodies?

ch substances are said to be *oxygenized*, or

body to form a chemical combination with the oxygen, that is furnished by the supporters of the combustion; and so intimate is this union in many instances, that it is only with extreme difficulty we can again separate the oxygen from the oxide.*

Is it possible to separate entirely the oxygen from burnt bodies?

Yes: these compounds may be de-oxidized in various ways;† and in some cases the oxygen may be transferred from the burnt body to a fresh

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* When oil is burnt in an Argand's lamp, its carbon unites with the oxygen of the atmosphere, and forms carbonic acid gas; while its hydrogen unites with another portion of oxygen, and forms water. Every 100 ounces of oil thus burnt produce 130 ounces of water. In these products of combustion the oxygen is more intimately combined than it was with caloric in the gaseous state. Hence we see what a beautiful series of changes and modifications the elements of matter are destined to undergo, and how admirably Nature has provided for the preservation of all her productions.

"To me be Nature's volume broad display'd;
And to peruse its all-instructing page,
My sole delight."

That the combustion of alcohol produced water, was known in the time of Boerhaave. By presenting a cold vessel to the flame of alcohol he collected water that was without taste or smell, and in every respect like distilled water.

† Water, as we have shown, is a product of combustion, and its base is hydrogen, the most combustible substance we are acquainted with. To restore the combustibility of the hydrogen, we have only to abstract its oxygen, which may readily be done by mixing iron or zinc filings, and sulphuric acid, with the water; by which means the metal becomes oxidized, and the hydrogen gas is evolved as combustible as ever. This may be adduced to show that the simple substances cannot be divested of their own peculiar properties by any of our mixtures, or even chemical combinations.

nbustible body, and be made the means of pro-
ing a fresh combustion; or it may sometimes
completely separated, and shown in its primi-
or gaseous state.*

What part of bodies is it which is destroyed by
bustion?

No part that we know of. We have reason to
nk that every particle of matter is indestructi-
, and that the process of combustion† merely
omposes the body, and sets its several com-
ient parts at liberty to separate from each
er, to form other new and varied combina-
ns.‡

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*This is frequently done for the purpose of procuring oxygen
The oxide of manganese, or of mercury, is exposed to a

What is the natural inference from this interesting fact?

The natural conclusion is, that nothing less than consummate Wisdom could have devised so beautiful a system, and that nothing short of infinite Power could have so modified matter as to subject it to the operation of such laws: laws which effect so many desirable purposes, and at the same time so effectually prevent* the destruction of those elementary principles, which are actually essential to the preservation of the world.

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* Perhaps it was in some such light as this that Pythagoras meant the metempsychosis to be understood. It might be a curious inquiry, whether or not he received this doctrine from the Egyptian priests, as they from the philosophers of India. An ancient Shastre, called the Geeta, has a beautiful stanza upon this subject, in which the varied form that the soul assumes is compared to a change of dress. The Baiseshec account of the Hindoo laws. Ovid, in the speech he gives to Pythagoras, compares it to wax, where the substance is always the same, though the outward form is varying. Dr. Darwin pursues the same idea in the following lines:

"Hence when a monarch's [illegible]
Awhile reflect the [illegible]
But, as a few short hours or years have flown,
Alchymic [illegible] dissolve,
Empires and [illegible]
Fresh [illegible] with [illegible]
With your [illegible]
And [illegible] for the rising [illegible]

CHAPTER XIII.

OF ATTRACTION, REPULSION, AND CHEMICAL AFFINITY.

WHAT is attraction?

ttraction is that unknown force which causes ies to approach each other.*

Which are the most obvious instances of attrac-
?

he gravitation of bodies to the earth; that of planets towards each other;† and the attrac-

Are you acquainted with any other instances of attraction?

Yes: attraction subsists likewise between the *particles** of bodies; and it is this kind of attraction which comes under the more immediate cognizance of chemists.†

How is this kind of attraction defined in chemical language?

Whenever the force of attraction operates between particles of the same species, it is called the attraction of *cohesion*,‡ or the attraction of

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compass; a guide on which they can rely at all times with perfect safety:

"So turns the faithful needle to the pole,
Tho' mountains rise between, and oceans roll."

DARWIN.

* If common flowers of sulphur and potass be mixed and thrown into water, the sulphur will separate and the potass be dissolved; but if they be previously melted together, the union will then be so perfect, that the compound will be completely soluble. The design of this experiment is to show that chemical affinity has no sensible action but on the mere elementary particles of bodies.

† All the operations of chemistry are founded on the force of attraction which nature has established between the particles of bodies, and by which force all bodies cohere. The art of chemistry employs different means to destroy this attraction of cohesion, and to form fresh substances by the means of new attractions. Take silex as an instance:—in this earth the attraction of cohesion is so strong, that the most powerful acids (one excepted) have no action upon it. But if the strength of this cohesion be broken by fusing it with an alkali, it then becomes obedient to some of the other acids, and may be held in solution by them.

Klaproth found that the ruby and the adamantine spar are scarcely affected by any chemical agent; but that, if their cohesion be destroyed, they are then acted upon, and their analysis can be accomplished.

‡ It is from the attraction of cohesion that a drop of water is

gation; but when between the particles of rent substances, it is then called the attraction *mposition*, or chemical *affinity*.*

n you explain with more precision what is meant traction of aggregation?†

he particles of all bodies are possessed of the

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s spherical, and that small particles of quicksilver are con- of a globular figure. In consequence of the same species action, particles of water and other liquids ascend in capil- ubes. If a small plate of glass be laid upon a globule of ry, the globule, notwithstanding the pressure, continues to ve its round figure. If the plate be gradually charged veights, one after another, the mercury becomes thinner inner; but, as soon as the weights are removed, its globu- ure is restored.

piece of loaf sugar broken into fine powder, or water in ate of vapour, is said to have its attraction of aggregation ; but the smallest atom of the powder is still sugar, and ost trifling portion of the vapour is still water. In order

inherent property of attracting each other, which causes them to adhere, and preserves the various substances around us from falling in pieces. The nature of this wonderful property is entirely unknown.

What do you understand by attraction of composition, or chemical affinity?

The particles of every simple substance have not only an attraction among themselves, forming the aggregation of that body or substance; but they have also another attraction to such other substances with which they have an affinity; and, when presented, unite to them, and form a new compound.*

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gently moved along a smooth surface towards each other, a mutual attraction of one to the other will be very evident at the moment of their union into one globule. Two small pieces of cork floating in a basin of water, if not nearer to the edge than to each other, will visibly approach, and at last come into contact:

"Hast thou not seen two pearls of dew
The rose's velvet leaf adorn,
How eager their attraction grew,
As nearer to each other borne?" DRUMMOND.

The force of the attraction of aggregation, in solid bodies, may be measured by the weight necessary to overcome it. Thus, if a rod of metal, glass, wood, &c. be suspended in a perpendicular direction, and weights be attached to its lower extremity till the rod breaks, the weight attached to the rod just before it broke, is the measure of the cohesive force of the rod.

* This power was by Bergman called *elective* attraction, as though matter were endued with the ability to prefer one substance to another. *Chemical attraction* is a more definite term, and is now in general use.

Those substances which are capable of uniting, are said to have a chemical affinity for each other: those which do not

*hat are the laws of chemical attraction?**

emical attraction can only exist between the cles of opposite and distinct substances ;† his species of attraction is exerted with dif- t force, according to the nature of such sub- es, and frequently in proportion to the mass. bodies combine only in certain propor- :‡—the new combinations acquire new pro- es,§ and are incapable of separation by me- ical means.

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a chemical union,' are said to have no affinity. The varied nce of this property of matter may be attributed by the t to *chance*; but the man of sober reflection, who allows vidence of a mass of facts to have its natural influence his mind, will be persuaded that chemical affinity can r be ascribed to accident, nor to a necessity in the nature ngs; for, perceiving that the works of nature and art are verned by this astonishing principle, he will attribute the

How are the different kinds of chemical attraction distinguished?

Chemical attraction is of three kinds; viz. simple attraction, compound attraction, and disposing attraction.

What is simple attraction?

When two substances unite merely in consequence of their mutual attraction, they are said to combine by virtue of simple attraction or affinity.*

What is compound affinity?

The action of two compound substances, where-

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sessed before their union; for the alloy formed will be a very brittle metal. If liquid ammonia and muriatic acid, both fluids of a strong odour, be mixed in proper proportions, a fluid will be produced entirely devoid of smell; viz. muriate of ammonia.

If nitrate of ammonia and sulphate of soda, both in crystals, be rubbed together in a stone mortar in equal proportions, the mixture will be converted to a fluid.

*The following experiments will serve to exemplify some cases of simple affinity:—Take a portion of acetate of soda, pour muriatic acid upon it in a retort, and distil it to dryness. The acetic acid will be expelled, and the muriatic acid will be found in combination with the soda, united so strongly that the most intense heat will not be able to separate it. This effect is owing to the soda having a greater affinity for muriatic acid than it has for the acetic. If a portion of nitric acid be now added to the muriate of soda, and heat applied, the muriatic acid will be again disengaged, and the nitric acid will be in possession of the soda. Lastly, if to the nitrate of soda sulphuric acid be added, and these exposed to a due degree of heat, the nitric acid will be expelled, and the sulphuric acid will be in possession of the alkali, forming a true sulphate of soda. These changes all take place in consequence of chemical attraction. By this attraction acetic acid combines with soda, and forms a salt called acetate of soda; but muriatic, nitric, and sulphuric acid have each of them a stronger affinity for soda, and their respective affinities are in the order in which they have been named.

ey mutually decompose each other, and pro-
two or more new compounds.*

hat do you mean by disposing affinity?

hen bodies, which apparently have no ten-
y to unite of themselves, combine in conse-
ce of the addition of another substance; the
n is said to be produced by means of *disposing*
ty.

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into a solution of sulphate of ammonia there be poured
acid, no decomposition is produced, because the sulphuric
as a stronger affinity than nitric acid for ammonia. But if
ion of nitrate of potass be poured in, we obtain by evapo-
two new bodies, viz. *sulphate of potass*, and *nitrate of*
nia. In this case, the sulphuric acid of the sulphate of
nia attracts the potass of the nitrate of potass, at the same
at the ammonia attracts the nitric acid; and to the agency
e united affinities the double decomposition must be at-
d. The manner in which these combinations take place
en explained by the following diagram, the idea of which

What other terms are employed on the subject of chemical affinities?

There are what are called *quiescent* attractions, and *divellent* attractions.

What do you mean by quiescent attractions?

When two or more bodies are presented to each other, the attractions which tend to preserve their original arrangement of parts are denominated the *quiescent* affinities.*

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dyers and calico-printers, cannot be formed by the direct mixture of its component parts: for acetic acid exerts no action upon alumine, however its parts may be divided by mechanical means. But if we mix sulphate of alumine with acetate of lead, a mutual decomposition will take place, and the article required will be produced.

If *concentrated* nitric acid be poured upon iron, there will be no union. The component parts of the nitric acid have so great an attraction for each other, that the iron has no power to effect a decomposition. But, if a few drops of water be added, the union between the oxygen and nitrogen of the nitric acid will be weakened, part of its oxygen will combine with the iron, a violent action will take place, clouds of nitrous gas will be disengaged in abundance, and the iron will soon be entirely dissolved in the acid.

* If a few drops of nitrate of silver be poured into a solution of muriate of soda, two new substances will be formed, viz. nitrate of soda, and muriate of silver; the latter of which, being insoluble in water, will be precipitated. In this experiment the affinity of the nitric acid to the silver, and the muriatic acid to the soda, are the *quiescent* affinities; whereas the affinity of the nitric acid to the soda, and the muriatic acid to the silver, are the *divellent* affinities. Hence no new arrangement of parts in any mixture can take place, unless divellent attraction exist.

Among the affinities of any substance, there is generally at least one peculiar to that substance which stamps it as one of its generic characters; and it is of the utmost importance to the student, in the more early stage of his progress, to imprint these characteristics upon his mind as often as he happens to meet with them. It is these predominating affinities which are more particularly serviceable in the classification of the

t is meant by divellent affinities?

se attractions which tend to destroy the ori-
compound, and to form new arrangements,
lled the *divellent* affinities.

t advantage do we derive from the study of
al attractions?

m all that has hitherto been explained, this
to be beyond doubt the most important
f chemistry; for it is only from a thorough
edge of the attractions which different sub-
s have for each other, that we shall ever
a complete analysis of the productions of
.

w should a pupil proceed to acquire,—what
so essential to chemistry,—a knowledge of
affinities?

column, and separated generally by a line; below this the other bodies are placed in the order of their attraction to the first substance:—thus, in respect to the affinities peculiar to *sulphuric acid*, it appears that barytes, which is the nearest, would separate strontian, potass, or any one of the succeeding substances, from sulphuric acid, which prefers barytes to all other bodies whatever.

Are these tables to be depended upon in every case of chemical composition and decomposition?

These tables, notwithstanding some excep-

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nature of all others. Let the question be Sulphuric Acid, and it will be formed thus:—

SULPHURIC ACID.

Barytes.
Strontian.
Potass.
Soda.
Lime.
Magnesia.
Ammonia.
Alumine.
Metallic oxides.
Water.

This table is designed to show that barytes has the strongest affinity for sulphuric acid, and will detach it from any of the succeeding substances in the list; and that strontian will separate it from potass, &c. &c. Actual experiment will confirm it

* are so extremely useful, that the study of
cannot be too strongly inculcated; for in
cases they may be safely trusted by the prac-
chemist.

at is repulsion?

pulsion is a peculiar property, inherent in the
les of all matter, which gives them a con-
tendency to recede from each other.†

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ie affinities of bodies are affected by the proportions in
they are presented to each other, by the cohesion of
irts, by chemical repulsion, &c. Berthollet has shown
ubstances are capable of decomposing each other reci-
y, if they be added respectively in the proper quantity.
ulphuric acid decomposes nitrate of potass altogether,
assistance of heat. The nitric acid is driven off, and
emains behind sulphate of potass. But if nitric acid be
into sulphate of potass *in sufficient quantity*, it takes a
the base from the sulphuric acid, and nitrate of potass
nerated. In like manner phosphoric acid decomposes

How does this property of matter operate?

It operates both at sensible and at insensible distances.

What instances are there of the former kind of repulsion?

The only kinds of repulsion that can be exhibited to the senses, are those of electricity* and magnetism;† but it is *insensible* repulsion with which chemists are more particularly concerned.

What instances have you of this latter kind, or of insensible repulsion?

The chief example that we are acquainted

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ficult to wet them. The spec. gravity of steel is much greater than that of water; yet if a dry steel needle be placed with care upon the surface of a basin of water, the repulsion of the water will prevent its sinking. Thus, some insects will walk upon water without any of it adhering to them;

"Or bathe unwet their oily forms, and dwell
With feet repulsive on the dimpling well."

* If two small pith balls be suspended from an insulated body with fine thread, so as to touch each other, and we charge that body with electricity, the pith balls will separate immediately. The balls, of course, *repel* each other.

Sir Humphry Davy has very satisfactorily shown, that those substances which are incapable of chemical combination are uniformly in the *same* electrical states; and that, according to the common laws of electricity, such bodies might be expected to repel, but cannot attract each other. See Phil. Trans. for 1807, page 1.

† When we present the north pole of a magnet A to the same pole of another magnet B, suspended on a pivot, and at liberty to move, the magnet B recedes as the other approaches; and by following it with A at a proper distance, it may be made to turn round on its pivot with considerable velocity. There is then a *repulsion* between the two magnets,—a repulsion which increases with the power of the magnets; and this power has been made so great, by a proper combina-

is the repulsion of the particles of caloric* ngst themselves; which repulsion would con- ly tend to infinite separation, were it not for emical union, which, by an irrevocable law of re, they form with the first surrounding body; y that law, it seems, the particles of caloric ot exist in an isolated state.

w does this repulsive force operate upon other s?

diminishes the cohesion of the integrant cles of all heated bodies, in consequence of particles of caloric repelling each other; so chemical unions, as well as chemical de-

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magnets, that all the force of a strong man is insufficient e the two north poles touch each other.

natural magnet is a ponderous iron-stone of a blackish

compositions, are wonderfully facilitated by this species of repulsion.*

Endeavour to explain this action of caloric with more precision?

As chemical affinity takes place only between the ultimate molecules of bodies, while the attraction of cohesion remains superior to that of affinity, no other union can take place; but whenever caloric has sufficiently diminished this attraction in any substance, the particles are then at liberty to form new combinations, by their union with the particles of other bodies.†

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* It is evident, that whatever diminishes the cohesion which exists between the particles of any body, must also tend to facilitate their chemical union with the particles of other bodies. One reason why some bodies require a high temperature to cause them to combine, is, that at a low temperature the attraction of cohesion is in them superior to that of affinity; accordingly it becomes necessary to weaken that attraction by caloric, till it becomes inferior to that of affinity. In like manner, bodies combine more easily when held in solution by water, or when they have previously been reduced to a fine powder, as these operations diminish the cohesion which exists among the primitive or integrant particles. Sulphuric acid has no action upon a lump of fluate of lime; but if that earthy salt be reduced to powder, a violent action will ensue on the addition of the sulphuric acid, and the fluate of lime will be decomposed.

† The formation of the red oxide of mercury will exemplify the above chemical axiom. If mercury be submitted to a heat little superior to that of boiling water, no new combination will be formed, but the metal will remain unaltered. If the heat be increased to 600°, or thereabouts, the attraction of cohesion of the mercury will be broken; its particles will unite with the oxygen of the surrounding atmosphere; and a new substance, *red oxide of mercury*, will be produced. If this new substance be again submitted to the operation of caloric, and the heat be raised to 1000°, the combination will again be broken, and new affinities will take place. The affinity of oxygen for caloric will now be greater than that of oxygen for mercury;

the [illegible]

st [illegible]

t [illegible]

Is the [illegible] of caloric always necessary to pro-

duce chemical changes?

In what manner does the attraction of composition may be said to exist between two bodies, it is generally necessary either that one of the substances should exist in a state of fluidity, or that heat should be applied: so that caloric acts an important part either sensibly or insensibly, in all cases of chemical affinity.*

Does chemical affinity operate in consequence of the universal law of attraction?

We have reason to believe that every new compound is produced by virtue of the attraction to which all matter is subject, and which is equally active on the most minute atom, as on a planetary system.†

*How do you imagine that the same force which operates upon the ultimate particles of bodies, so as to produce composition and decomposition, can be sufficient to preserve the planets in their orbits?**

"We can neither comprehend the one nor the other; nor can we see why the Almighty might not as easily bestow upon one species of matter the power of acting upon another when at a distance,† as the power of being acted upon

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* A passage of Bishop Watson's will perhaps furnish as good a reply to this question as can be given. "We feel," says he, "the interference of the Deity every where, but we cannot apprehend the *manner* of his agency any where. A blade of grass cannot spring up, a drop of rain cannot fall, a ray of light cannot be emitted from the sun, nor a particle of salt be united, with a never-failing symmetry, to its fellow, without him; every secondary cause we discover, is but a new proof of the necessity we are under of ultimately recurring to him as the one primary cause of every thing."

† Dr. Herschel has shown, that not only the planets in our system are preserved in their orbits by mutual attraction, but that in the sidereal systems the double stars are so situated with respect to each other, that *they* must be subjected to mutual gravitation, and that they can only preserve their relative distances by a periodical revolution round a common centre. What he calls the *insulated* stars he imagines to be nearly out of the reach of mutual gravitation. He considers our sun and all the bright stars to be of this class. They are at such immense distances, that he calculates that Sirius, the nearest of the fixed stars to us, and the Sun, if the power by which they are preserved in their orbits were withdrawn, would be 33 millions of years in falling together. The same philosopher has said, that though light travels at the astonishing velocity of 200,000 miles in a second, some of the double are so far from us, that the rays of light must have been nearly two millions of years in passing from them to our system. According to a writer in the fifty-second volume of the Monthly Review, N. S. 525, astronomers are now acquainted with no less than 2120 of these marvellous stars. Probably they are so many distinct worlds, appropriated by the Author of Nature for the re-

changed by matter when in actual con-
"*

the consideration of this universal property of
er calculated to produce any peculiar reflec-
?

he contemplation of this subject has a natural
ency to promote the most profound feelings
we and admiration; for the understanding
he highest intelligences sinks into nothing,
n compared with the energy of that Omni-
nt Being, who had wisdom to contrive,
ability to endue the matter which he had
ed with the astonishing power of operating
its fellow matter, either in contact, or when
rated by the infinity of space. Well might
iter of antiquity assert, that "God saw every
that he had made, and behold it was very

ADDITIONAL NOTES.

I.

Of Specific Gravity.

common method of taking the specific gravity of the or of any solid body, is by comparing the difference here is in their weight when weighed in air and in wa- at is, to divide the *absolute* weight by the *loss*, and the t is the specific gravity. Thus, if a mineral, which weighs unces in air, weighs only two ounces when weighed in the specific gravity of such mineral is 3; that is, if water, nerally is, be called 1.000, the substance now examined); or, to make it plain to the young student, if a pint of veigh *one* pound, the same *bulk* of the mineral will weigh ounds. See page 35.

ore ready way to determine the specific gravity of solids l a phial with water, and note the weight of the whole ely in grains. Then weigh 100 grains of the mineral or ubstance to be examined, and drop it gradually into the f water. The difference of weight of the bottle with tents now, and when it was filled with water only, ve the specific gravity of the matter under examination. ample, if the bottle weighs 50 grains more than it did t was filled with water only, it shows that 100 grains of neral displace only 50 grains of water, and consequently is twice the specific gravity of water. This method to have been discovered by Archimedes. See Note *, 2.

specific gravity of fluids is generally determined by an eter, which is a graduated glass tube with a bulb, so ed that it may swim in the fluid in a perpendicular po- The specific gravity is shown by the degree to which strument sinks in the fluid to be examined, and this nsequently always be lower in proportion as the liquid er.

The specific gravity of ardent spirits is generally ascertained by means of a hydrometer, of which various kinds are sold by the mathematical-instrument-makers.

The following method, which was contrived by Dr. Lewis, the celebrated author of the Commercium Philosopheo-Technicum, was communicated to me by the amiable Samuel Moore, esq. late secretary to the Society for the promotion of arts, manufactures, and commerce.

In this method the specific gravity of a liquor is estimated from the excess of the weight of a certain measure of it above that of an equal measure of distilled water. A set of weights is made for this purpose, called *carats*, or *caratkes*, in the following manner:—

A convenient bottle being procured, the tare of the bottle is first taken; it is then completely filled with distilled water; the weight of the water is accurately divided into two equal parts, and a weight made equal to one of these parts is marked 64: by continuing the division, are obtained the weights 32, 16, 8, 4, 2, 1, carats; so that a carat is the 128th part of the weight of the water. Another weight is then made which counterpoises the bottle when filled with water; and so many carats as the bottle filled with an alkaline ley, or any other liquor, weighs more than this waterpoise, so many carats strong is the liquor said to be.

In taking the specific gravity of bodies, an attention should always be paid to their temperature, as the specific gravity of a body, when expanded by caloric, will always be less than it is when at a low temperature.

II.

Of a curious Property of Charcoal.

A property of which charcoal is very eminently possessed, and which may be regarded as a singular one, is that of absorbing, even when cold, aëriform fluids, and condensing them in its pores, in quantity exceeding many times its own bulk. A very interesting application may be made of this property. The gases which are absorbed suffering so great a condensation, two gases introduced at once into the pores of the charcoal may perhaps be made to combine. It appears from the 32d vol. of the Annales de Chimie, that water has actually been formed by this means. The subject deserves to be prosecuted; and if strong mechanical pressure were applied at the same time, it is probable such combinations might be diversified, and carried to a greater extent. More on this subject may be seen in Murray's Chemistry, 2d edition, vol. ii. page 330; and in the Journal de Physique for 1788.

III.

Of Ebullition.

Under an exhausted receiver, water will boil at the heat of 92° of Fahrenheit's thermometer; whereas, under the usual pressure of the atmosphere, it does not boil till it is heated to 212°; though, as the atmosphere varies in density, it occasions some little variation in this respect; for Sir George Shuckburgh found by experiment, that when the barometer was at 26 inches, water boiled at less than 205 degrees, but when it was at 31 inches it required to be heated to near 214° before it would boil.

Under the common pressure of the atmosphere

Ether boils at . . .	96°
Alcohol	176
Water	212
Nitric acid	248
Sulphuric acid . . .	546
Phosphorus	554
Mercury and Linseed oil . .	600

Dr. Black made experiments upon several liquids in vacuo, and found that in general they all boiled with about 140 degrees of heat less than when bearing the weight of the atmosphere. Vitriolic ether (if the pressure of the atmosphere be removed) will boil when 52 degrees below the cold sufficient for freezing water. See pages 49 and 97.

IV.

Of the Combinations of Caloric.

When water is in the state of ice, it combines with caloric, without discovering by the thermometer any rise of temperature; but the moment the whole becomes fluid, every addition of caloric expands the mercury in the thermometer till the water arrives at 212°, when on a sudden the thermometer ceases to rise, though the water continues to receive and combine with a vast quantity of caloric. On these curious facts Mr. Murray has remarked, "We see no cause why, for a great extent of the thermometrical scale, bodies should receive caloric without entering with it into any intimate combination; why, when the temperature is raised to a certain point in each body, this combination should suddenly take place; and why, after another interval in the thermometrical scale, it should be renewed; for example, why water at 32°, and, under the

common atmospheric pressure, at 212°, and at those points *only*, should contract an intimate union with caloric." It is true, the cause which produces these effects is concealed from our investigation, but the uses of this order of things are many and important. See Notes, pages 82, 87, and 93. In addition to those facts, other important results, from these seeming anomalies of nature, must present themselves to every contemplative mind, affording it fresh assurances that nothing but beneficence united with consummate wisdom could have dictated such curious and efficacious deviations in the established laws of the universe.

" 'Twas this that guided thy Almighty hand,
When formless chaos heard thy high command;
When, pleas'd, thy eye the matchless work review'd,
And goodness placid spoke 'that all was good.'"

V.

Of Water.

In addition to what has been said in the note to chap. iii. p. 94, on the peculiar law which water observes during its change of temperature; it is worthy of notice, that as rivers, lakes, &c. give out caloric to the currents of cold air passing over them, the upper stratum of water becomes of greater specific gravity, and therefore sinks, and that this occasions the rise of a portion of warmer water which gives out its caloric in like manner; and that this constant circulation very much contributes to moderate the rigour of winter throughout the temperate zones. In the ocean and other deep bodies of water, this circulation goes on for a considerable time, and an immense quantity of caloric is thus thrown into the atmosphere:—but if no limit had been put to this process, what would have become of those innumerable tribes of creatures that inhabit this element? The exigency has however been admirably provided for by the Author of Nature; for whenever the whole mass of water arrives at the temperature of 42°—5, its specific gravity no longer increases by the further diminution of its temperature, and the circulation that we have been speaking of entirely ceases. How completely does this simple deviation from a general law answer all the purposes for which it was intended!

" Such the all-perfect hand
That pois'd, impels and rules the steady whole."

On the top of a hill near Lochness, in Scotland, whose perpendicular height is nearly two miles, there is a small lake o

fresh water, hitherto said to be unfathomable, which never freezes during the coldest winters. Here the depth is so great, that the circulation is not completed before the return of summer; whereas the Lochanwyn, or Green lake, 17 miles distant, is perpetually covered with ice.

VI.

Of Oxygen Gas.

Details of several surprising cures by means of oxygen gas have been given in the different volumes of Mr. Tilloch's Philosophical Magazine.* By the new invented gasometers, and the apparatus sold with them, any kind of factitious air may be accurately measured, and mixed with any portion of atmospheric air that the physician may prescribe. See page 58. And notwithstanding the ridiculous effects which have been attributed to pneumatic medicine, by the over sanguine practitioner, there can be no doubt but that the addition of more oxygen gas to atmospheric air, when aided by proper tonics, has in many instances been very efficacious, and peculiarly so in those female complaints which arise from want of sufficient tone and vigour in the system.

Thus the afflicted, feeble, sickly maid,
Whose spirits languish, and whose health declines,
Looks to pneumatic chemistry for aid,
And on that science every hope reclines.

Anxious she marks the mixture of the airs,
And joys to hear them bubble and expand;†
While fell Hysteric every sinew tears
And overwhelms her with his leaden hand.

Trembling she grasps the cold metallic tube,
In fear mysterious, and with caution drinks;
While every pulse acquires a kinder throb,
And still increases as the column‡ sinks.

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* See also an interesting "Essay on the Medicinal Properties of Factitious Airs," by Tiberius Cavallo, Esq. 8vo. Dilly, 1798.

† When the oxygene gas is prepared, it is thrown up through water into the gasometer in bubbles, where it expands and mixes with the atmospheric air, previously measured into it.

‡ The gasometer is covered by an inverted cylindrical vessel which preserves the air from escaping; this is fixed upon pulleys, and sinks lower and lower in the water, as the gas is inhaled from underneath it.

The heaving lungs inhale the vital gas,
The blood absorbs it as it ebbs and flows;
It gives fresh colour to the fluid mass,
And the whole frame with pristine vigour glows.

Returning health adorns the roseate cheek,
And decks the features with its every charm;
While new designs new energies bespeak,
And Beauty's self resumes her native form.

With emulation now her bosom burns;
The grateful female cultivates her mind,
And feels the sweetest pleasure while she learns
The science* sent by Heaven to bless mankind.

VII.

Of the Production of Oxygen Gas.

gen gas may be procured in any quantity from the black
of manganese, which is a cheap article. It is only neces-
pulverise the manganese, and expose it in an iron retort
oper degree of heat. The gas, which will rise in great
from the retort, may be received in bladders or any ap-
ite vessels. Dr. Priestley, who discovered this air, called
logisticated air. According to Mr. Parkinson, one pound
anese will furnish ten gallons of this gas. It may be

again made to collapse and distend, by the inflation of common air, the blood in the pulmonary vessels regained its former crimson colour, and the action of the heart and arteries was excited anew. *Philosophy of Medicine.* See page 62 of this volume.

IX.

Of the Circulation of the Blood.

According to Dr. Thomson, one principal use of the blood is to furnish fibrina to supply the waste of the muscles; for as neither the chyle nor the lymph contains fibrina when they flow into the blood, there must be a continual decomposition of chyle and lymph in the blood vessels, in order to form this substance. We know that carbon and hydrogen are thrown out by the act of respiration; he therefore concludes that one use of the air absorbed is to abstract a quantity of carbon and hydrogen from the chyle, by compound affinity, in such proportions that the remainder becomes fibrina.* For the information of young readers, the following account of the apparatus for elaborating the blood is copied from Paley's Natural Theology:

"There is provided in the central part of the body a hollow muscle, invested with spiral tubes, running in both directions. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain. by the relaxation of the same fibres, the cavities are in their turn dilated; and, of course, prepared to admit every fluid which may be poured into them. Into these cavities are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back. This is a general account of the apparatus: and the simplest idea of its action is, that by each contraction a portion of blood is forced as by a syringe into the arteries: and at each dilation an equal portion is received from the veins. This produces, at each pulse a motion and change in the mass of blood to the amount of what the cavity contains, which in a full-grown human heart is about an ounce, or two table-spoons full. Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour; from which it follows, that there pass through the heart every hour four thousand ounces, or 350lbs. of blood. Now the whole mass of blood is about 25 pounds; so that a quantity of blood equal to the whole blood within the body passes through the heart fourteen times in one hour;

* System of Chemistry, vol. iv. 725.

which is about once every four minutes. Only consider what this is in very large animals. The *aorta* of a whale is larger in the bore than the main pipe of the water-works at London bridge; and the water roaring in its passage through that pipe is inferior in impetus and velocity to the blood gushing from the whale's heart." According to Dr. Hunter, ten or fifteen gallons of blood are thrown out of the heart of a whale at a stroke, with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder. See Dr. Hunter's account of the dissection of a whale, in the Philosophical Transactions.

"It was necessary, that the blood should be successively brought in contact or proximity with the air; therefore, as soon as the blood is received by the heart from the veins of the body, and before that it is sent out again into its arteries, it is carried by the force of the contraction of the heart, and by means of a supplementary artery, to the lungs; from which, after it has undergone the proper change, it is brought back by a large vein once more to the heart, in order, when thus prepared, to be from thence distributed anew into the system. See page 83.

"An anatomist, who understood the structure of the heart, might say beforehand that it would play: but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement; or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time without disorder, and without weariness."

X.

Of the Renovation of the Atmosphere.

It has been imagined that the atmosphere is occasionally renovated from other sources than those mentioned pages 66 and 67. Dr. Darwin, in his dissertation on the winds, concludes that immense masses of air are set at liberty from their combinations with solid bodies, within the polar circle, or in some region to the north of us; and that they thus perpetually increase the quantity of the atmosphere; and that this is again at certain times re-absorbed, or enters into new combinations at the line or tropical regions: by which means the atmosphere is perpetually renewed, and rendered fit for the support of animal and vegetable life. Botanic Garden, page 28.

The following idea is merely hypothetical, but it deserves perhaps some notice.—"The *moisture* contained or dissolved in the ascending heated air at the line, must exist in great *tenuity*, and by being exposed to the great light of the sun in that climate, the water may be decomposed, and the new airs spread on the atmosphere from the line to the poles."—*ibid* page 86.

"On liquid air Hs bade the columns rise,
That prop the starry concave of the skies;
Diffus'd the blue expanse from pole to pole,
And spread circumfluent ether round the whole."

BLACKLOCK.

The action of the sea also has probably considerable influence in purifying the atmosphere: indeed, from some experiments related in Murray's Chemistry, 2d edit. vol. ii. page 154, it appears that water always gives out oxygen in the act of freezing. See Chap. ii. page 84; and Additional Notes, No. XVIII.

XI.

Examples of Affinity.

Take a little common magnesia, and pour by degrees diluted nitrous acid upon it till the whole of the earth be dissolved. This is an instance of simple chemical affinity. But if a solution of potass be poured upon the former mixture, the potass having a greater affinity for the acid, will take it from the magnesia, and the magnesia will again be precipitated.

To a solution of soap add a little weak sulphuric acid. The acid having a stronger affinity for the alkali of the soap than the alkali has for the tallow, the acid will unite with the alkali, and the separated tallow will be seen to float upon the surface of the liquor.

Dissolve a few ounces of sulphate of iron in water, by adding the salt by degrees till the liquor becomes turbid; then, if a skein of cotton thread be dipped in the solution and shaken a little in it, the thread will take up the whole of the oxide of iron, and render the liquor transparent. This effect is produced in consequence of the great affinity which cotton has for the oxides of iron.

If mercury be put into a *glass* bottle, the surface will appear convex, owing to the small affinity which mercury has with glass; but if it be put into a *metallic* vessel, the surface of the mercury will appear concave like that of other fluids, because of its tendency to combine with the sides of the vessel. This may be adduced as a striking proof of metallic elective attraction.

The phenomena of dyeing may also be referred entirely to

chemical principles. The colouring particles possess chemical properties that distinguish them from all other substances; they have attractions peculiar to themselves, by means of which they unite with acids, alkalies, metallic oxides, and earths. The difference in the attractions of the colouring particles for wool, silk, and cotton, is sometimes so great that they will not unite with one of these substances, while they combine very readily with another: thus *cotton* receives no colour in a bath which dyes *wool* scarlet."—*Berthollet*, vol. i. page 22. Several curious and instructive instances of the effects of chemical affinity in the art of dyeing may be seen in that work, vol. i. 29, and following pages.

Chemical affinity may be pleasingly illustrated by the composition and decomposition of writing-ink. Take a little tincture of galls, and a little of the solution of green copperas, both colourless liquors, and, if poured together, the mixture becomes black, from the affinity which gallic acid has for the oxide of iron in the copperas. Then pour in a little weak aquafortis, and the liquor will become immediately transparent: this arises from the metal leaving the first acid to unite with the last, to which it has a greater affinity. But if a solution of potass be now added, the nitrous acid will quit the iron, and unite with the alkali thus the iron being once more disengaged, will again be caught by the gallic acid in the infusion, and once more produce a black liquor. See page 90.

Many other instances of chemical affinity will be found in Chap. xiii and in the Chapter of Experiments.

XII.

Atmospheric Pressure.

The rise of water in a pump was formerly attributed to the horror that nature had of a vacuum. This absurd notion was refuted about the middle of the seventeenth century, by the following occurrence.

The Duke of Florence, having occasion to raise water to the height of 50 or 60 feet, ordered a common pump to be made for that purpose; but when it was completed, the workmen were astonished to find that it would not work.

The matter was referred to the celebrated Galileo, but he was unable to account for it in any way. All they were able to determine was, that water would not rise in a common pump more than from 32 to 33 feet. The fact remained inexplicable till philosophers caught the idea of atmospheric pressure: since when, the suspension of mercury in the barometer, and water in a pump, have been well understood. See page 17

XIII.

Of the Formation of Water.

In 1798 Mr. Seguin made a grand experiment for the composition of water. He expended no less than 25,532 cubic inches (or nearly two hogsheads) of inflammable air, and 12,457 of vital air. The first weighed 1033 grains, and the second 6210, amounting to 7249 grains, and the water obtained amounted to 7245 grains, or about three-fourths of a wine pint. The loss was only four grains. Another experiment was afterwards made by Le Fevre, in which nearly two pounds and a quarter of water were produced.* See page 105.

XIV.

Of the Giants' Causeway.

The Giants' Causeway in the county of Antrim in Ireland, is the most remarkable one of its kind in the world. The name of it may naturally convey to us the idea of some stupendous work of art; and as such it seems to have been considered in the days of ignorance, when the name was first applied: modern philosophy, however, looks on it with a different eye. To conceive a proper idea of this unparalleled curiosity, we may imagine an approach to it from the sea: its first appearance is that of a bold rocky shore, with extensive ranges of shelving, calculated for an immense promenade. These rocks, however, instead of being disposed in laminæ or strata, form basaltes or angular columns, so closely attached to each other, that, though perfectly distinct from top to bottom, scarcely any thing can be introduced between them. Some account of this stupendous object of curiosity has already been given at page 236; but as the whole is still more curious in its minute parts than in the great, the following additional particulars will perhaps not be thought uninteresting.

The columns themselves are not each of one solid stone in an upright position, but composed of several short lengths exactly joined, not by flat surfaces, as in works of art, but, what is most extraordinary, they are articulated into each other, as a bone is into its socket, the one end of the joint having a cavity into which the convex end of the opposite is exactly fitted: which

* Dr. Black, vol. ii. page 236

is not visible but by disjointing the two stones. The depth of the concavity is generally from three to four inches; and what is still further remarkable, the convexity and the corresponding concavity are not conformed to the external pentagonal figure of the column, but exactly round, and as large as the size of the column will admit. It is still further remarkable, that the articulations of these joints are frequently inverted. In some the concavity is upwards, in others the reverse. A part of one of these columns was exhibited in the Leverian Museum, and is probably still in the possession of Mr. Parkinson.

The formation of this curious natural production has been accounted for by supposing that the whole body of the rock was once in a state of fluidity, being no other than the lava of a burning mountain; that the prodigious mass cracked in its cooling into the forms which we now see; that it may since in some measure have been deranged by earthquakes; that these have swallowed up the volcano itself; and that the waters of the neighbouring ocean now roll over the place where it once stood.* Those geologists, however, who have embraced the system of Werner, attribute all these effects to the agency of water. Can any thing be more gratifying to a well-informed mind, than the examination of these arcana of nature? "The sensualist may imagine that he enjoys the world; but to enjoy it truly is to be sensible of its greatness and its beauty."

"Presented to the cultur'd eye of taste,
No rock is barren, and no wild is waste."

XV.

Of Crystallization.

Gahn had observed, that in breaking a pyramidal crystal of carbonate of lime, it afforded rhomboidal fragments, of which it appeared to be entirely formed. Bergman from this conceived the idea, that in every crystal there exists a primitive form, from which the actual forms, having often no resemblance to it, may be generated by the superposition of decreasing laminæ; and that, by the mechanical division of crystals, this form may be detected, and the laws by which it gives rise to the different crystals determined. This is the basis of the system of Haüy. He demonstrated what Bergman had scarcely more than imagined. He succeeded in showing that in every crystallized substance, whatever may be the difference of figure

* Walker's Geography.

which may arise from modifying circumstances, there is, in all its crystals, a *primitive* form, the nucleus, as it were, of the crystal, invariable in each substance, giving rise to the actually existing outward forms.

It is well known to those who work on gems, that crystals can be mechanically divided only in certain divisions, so as to afford smooth surfaces, and that, if separated in any other way, the fracture, instead of being polished like the others, is rugged, and uneven. Ample extracts from the work of the Abbé Haüy will be found in the first vol. of the Philosophical Magazine. See also Murray's System of Chemistry, vol. i. 48.

XVI.

Of Combustion.

In addition to what has been said, Chap. xii. of the effects of combustion, it may be remarked, that animal and vegetable substances are converted into water and carbonic acid during this process, by the union of their hydrogen and carbon with the oxygen of the atmosphere; and that, in time, the same water and the same carbonic acid are absorbed by vegetables, and again decomposed in order to set the oxygen at liberty to produce fresh combustions, while the vegetating organs appropriate the hydrogen and carbon to promote their growth and nourishment. A regular circle of compositions and decompositions is thus perpetually going on, and all organized beings are made to surrender in due time, to the general mass, those elementary substances which nature kindly lent them for the preservation of their existence. See page 105. Is not this admirable simplicity of nature a conclusive proof of the infinite wisdom of the Deity, and that the greatest possible sum of utility and of happiness was his ultimate object?

"The whole and every part proclaims
His infinite good-will;
It shines in stars, and flows in streams,
And bursts from every hill.

We view it o'er the spreading plain,
And heavens which spread more wide;
It drops in gentle showers of rain,
And rolls in every tide."

BROWNE.

very made by Mr. Harrop, and which I have n... 113 of this work, adds another source to those already en... rated by M. Poiret, to prove the diminution of water. ...s discovery announces a power in nitrogen gas to absorb oxygen from water, till the mixture of nitrogen and oxygen arrives at that proportion which constitutes atmospheric air.

"Water restrain'd gives birth
To grass and plants, and thickens into earth;
Diffus'd it rises in a higher sphere,
Dilates its drops, and softens into air:
Those finer parts ... ire,
Move into warmth ... nto fire:
That fire once more, ... r o'ercome,
And downward forc'd ... arth capacious womb,
Alters its particles, is ire no m...,
But lies metallic dust, or pond'...us ore." PRIOR.

XIX.

Morveau's Preservative Phials.

The portable phial contrived by Morveau for preventing contagion may be prepared thus:

Forty-six grains of black oxide of manganese in coarse powder, are to be put into a small strong glass phial, with an accurately ground stopper, to which must be added about two drachm measures of nitric acid of 1.400 specific gravity, and an equal measure of muriatic acid of 1.134; the stopper is then to be replaced, and the whole secured by inclosing the phial in a strong wooden case, with a cap which screws down so as to keep the stopper safe. It is to be used in hospitals, or other places of infection, by simply opening the phial, with the nose averted, and replacing the stopper as soon as the smell of the oxymuriatic gas is perceived. A phial of this kind, properly prepared, may be used several years without losing its effect. The mixture, however, ought not to occupy more than one-third of the bottle.

XX.

Of Lime and Water Cement.

Dr. Watson has remarked, that "in countries where they have no common materials for making lime, it would be worth while for the farmer to examine the earth which may be met

with on the surface of the ground, or at a little distance below it; for that calcareous substances are not always united into hard compact masses, but are sometimes found in the form of loose earth, and that of different colours."

While writing on lime, some persons may be glad to be informed how a cement may be made with common lime, that will harden under water. What is called *poor* lime has this peculiar property; but as this species of limestone rarely occurs, it is often an expensive article. The following is a good substitute, and may be used for water-cisterns, aqueducts, &c.—Mix four parts of gray clay, six of the black oxide of manganese, and ninety of good limestone reduced to fine powder; then calcine the whole to expel the carbonic acid. When this mixture has been well calcined and cooled, it is to be worked into the consistence of a soft paste with sixty parts of washed sand. If a lump of this cement be thrown into water it will harden immediately. Such mortar, however, may be procured at a still less expense, by mixing with common quick-lime a certain quantity of what are called the *white* iron ores, especially such as are poor in iron. These ores are chiefly composed of manganese and carbonate of lime, or chalk. Common lime and sand only, whatever may be the proportion of the mixture, will certainly become *soft* under water.

XXI.

Of Light.

This work being intended to teach only the first principles of natural and chemical philosophy, I purposely omit entering into a general investigation of the nature of *light*. It is a subject but imperfectly understood, and what is known is in general too abstruse for the comprehension of youth, till they have made very considerable proficiency in other branches of knowledge. The *velocity* of light is however so admirably calculated to impress the young mind, that I could not resist making the following extract from Dr. Thomson's System of Chemistry:—

"It has been demonstrated that light takes about eight minutes in moving across one half of the earth's orbit: consequently it moves at the astonishing rate of 200,000 miles in a second; therefore, if each of its particles weighed the thousandth part of a grain, its force would be greater than that of a bullet discharged from a musket. Were it even the millionth part of a grain in weight, it would destroy every thing against which it struck. If it even weighed the millionth part of *that*, it would still have a very sensible force. But how

much less must be a particle of light, which makes no sensible impression upon so delicate an organ as the eye! We are certain then that no particle of light can weigh $\frac{1}{1000\,000\,000\,000}$th of a grain."* See page 368.

It may be remarked, that light "sets out from the body of the sun with a velocity equalled only by the extent of its journey. It goes from planet to planet, from sun to sun, distributing colours, illuminating and enlivening all nature. It never travels by circuitous routes, like the other great bodies which traverse void space, but passes on in straight lines; and if it does not pass through or combine with the bodies it meets, it is reflected back on other objects. It seems to be destined for the benefit of the whole universe, and consequently travels over all."—*Physical and Metaphysical Inquiries.*

" 'LET THERE BE LIGHT,' the great Creator said,
His word the active child obey'd;
Awhile the Almighty wondering view'd,
And then himself pronounc'd it good."

YALDEN.

XXII.

Of the Nature and Formation of Nitre.

The greatest part of the nitre we have is brought from the East Indies. See page 222. Should this supply fail, it may, after the example of the French, be formed artificially in Europe. During the second and third years of the French republic, the government required every district to send two intelligent young persons to Paris. This convocation, consisting of nearly eleven hundred individuals, received regular instruction from their first chemists, partly concerning the manufacture of cannon, and partly concerning the making of saltpetre for gunpowder. This body of pupils was afterwards distributed among the different establishments in proportion to their abilities, and saltpetre was soon furnished by them in abundance. Ann. de Chim. xx. 298.

It is suspected that the French, in this unexpected production of nitre, availed themselves of a discovery of our countryman Dr. Milner, who formed nitrous acid by passing ammonia over oxide of manganese placed in a tube, and submitted to a red heat.

The theory of the formation of nitre was little known till

* Thomson's Chemistry, vol. i. 279.

lately. An admirable paper on this subject, by Chaptal, occupying 47 pages, may be seen in the Annales de Chimie, tom. xx. Annexed is a useful paper on the refining of salt-petre. Also a paper by Guyton on the same subject, tom. xxiii. of the same work.

A great quantity of nitre is used by the makers of oil of vitriol. It is ground small, and mixed with sulphur, in order to afford oxygen to the sulphur while burning. For the same purpose it was used by the ancients in that destructive composition of antiquity called the *Greek fire*. Sulphur, resin, alcohol, camphor, and other combustibles, were melted with it, and in this melted mass woollen cords are dipped, which were afterwards rolled up for use. These balls being set on fire were thrown into the tents, &c. of the enemy; and as the combustibles were furnished with a constant supply of *oxygen* from the nitre, nothing could extinguish them.

When Constantinople was attacked in the reign of Leo, many of the ships of the besiegers were destroyed by this chemical composition. For many centuries the method of making this dreadful article of destruction was lost; but it has just been re-discovered by the librarian of the elector of Bavaria, who has found a very old Latin manuscript which contains directions for preparing it.

XXIII.

Of Muriate of Lead.

Muriate of lead, which is readily made, will afford the pupil a pleasing example of metallic crystallization. Take common red litharge, pour over it one third of its weight of good strong muriatic acid, and stir it well with the litharge. When it has stood to become dry, melt it in a crucible, and pour it into a metallic vessel in a state of fusion. The cooled mass will be of a beautiful brilliant yellow, and when broken will exhibit the most regular crystallization that can be conceived. See page 236.

XXIV.

Of the Uses of Alum.

The employment of alum in the arts is very extensive. It is used in dyeing, to fix a variety of vegetable colours, which otherwise would be fugitive. By means of this salt we are

enabled to obtain the admired colour* of the ancients, called the Tyrian purple, which on pain of death none but the Cæsars could wear. It is of service in the manufacturing of candles, giving consistence and firmness to the tallow. It is employed in the cod-fisheries, when the fish are prepared for drying, having the property of preventing the salt from deliquescing. In the art of tanning it gives a firmness to the skins after they have become flaccid in the lime-pits. It is used also in other preparations of leather. Its efficacy in preventing the bad effects of damp atmospheric air on preserved fish has been mentioned: with the same design it has been used in preparing paper for the preservation of gunpowder; and when used thus, it is of further service by preserving the paper from readily taking fire. But one of the most striking advantages of this important salt is in the preparation of acetate of alumine for the calico-printers; an article which, in the present improved state of the arts, the manufacturer cannot dispense with. It is prepared with acetate of lead, by a double decomposition. An easy way to prepare it is related in Berthollet's Treatise on Dyeing, in Thomson's System of Chemistry, &c.

XXV.

Of Carbon and its Combinations.

Carbon, whether we regard it in its most simple state, the diamond, or in that of common charcoal, is not only indestructible by age, but in all its combinations, which are infinitely beyond our comprehension, still preserves its identity. In the state of carbonic acid it exists in union with earths and stones in unbounded quantities; and though buried for thousands of years beneath immense rocks, or in the centre of mountains, it is still carbonic acid; for no sooner is it disengaged from its dormitory than it rises with all the life and vigour of recent formation, not in the least impaired by its torpid inactivity during a lapse of ages. Is not the consideration of this subject calculated to afford a strong and satisfactory analogical argument in favour of human resuscitation? "Tu perire et Deo credis, si quid oculis nostris hebetibus subtrahitur! Corpus omne, sive arescit in pulverem, sive in humorem solvitur, vel in cinerem comprimitur, vel in nidorem tenuatur, subducitur nobis, sed Deo elementorum custodi reservatur."—*Minucius Felix, edit. Ouzelii*, p. 326.

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* See Introduction to Berthollet on Dyeing, page 19.

XXVI.

Of Chemical Decomposition.

The changes which matter perpetually undergoes by the decomposition of all organized beings, probably gave rise to the ancient doctrine of transmigration. See page 55 and 374.

" The sacred seer, with scientific truth,
In Grecian temples taught the attentive youth,
With ceaseless change how restless atoms pass
From life to life, a transmigrating mass;
Whence drew the enlighten'd sage the moral plan,
That man should ever be the friend of man;
Should eye with tenderness all living forms,
His brother emmets, and his sister worms!"

DARWIN.

XXVII.

Of the Manufacture of Shot.

The manufacture of small shot is curious, and will probably amuse the young reader. In melting the lead, a small quantity of arsenic is added, which disposes it to run into spherical drops. " When melted, it is poured into a cylinder whose circumference is pierced with holes. The lead streaming through the holes, soon divides into drops which fall into water, where they congeal. They are not all spherical; therefore, those that are must be separated, which is done by an ingenious contrivance. The whole is sifted on the upper end of a long smooth inclined plane, and the grains roll down to the lower end. But the pear-like shape of the bad grains makes them roll down irregularly, and they waddle as it were to a side; while the round ones run straight down, and are afterwards sorted into sizes by sieves. The manufacturers of the patent shot have fixed their furnace, for melting the metal, at the top of a tower 100 feet high, and procure a much greater number of spherical grains, by letting the melted lead fall into water from this height, as the shot is gradually cooled before it reaches the water."* See pages 330 and 344.

XXVIII.

Of the Manufacture of White Lead.

Most of the manufactures of white lead are conducted in a mode somewhat similar to that related at page 363; but at

* Dr. Black, vol. ii. page. 604.

, near Dudley, there is a very large establishment for
paration of white lead on a different principle. Muriate
a is there decomposed by means of litharge; and as the
comes disengaged, the muriatic acid combines with the
e, and forms *muriate of lead*. I have reason to believe
rbonate of soda is employed for the decomposition of the
muriate, and that from thence results the carbonate of
hich is the product of the manufactory. The manufac-
of earthen-ware in the Staffordshire potteries are chiefly
d with this lead. Great quantities of it are also exported
erica.

XXIX.

Of Water-gilding.

e persons may be glad to be informed how the process
er-gilding is conducted. It is done by previously clean-
per, intended to be gilt, with sand and weak aquafortis;
which the piece is plunged in a diluted solution of mer-
the mercury leaves its solution, and precipitates itself
the copper: this causes the amalgam of gold, which is

whole plate.* For a more particular account of these processes consult La Grange, vol. ii. 80. There are two kinds of tin known in commerce; viz. *block* tin and *grain* tin. Block tin is procured from the common tin ore, and is usually cast in blocks of about 320 pounds weight; after which it is taken to the proper offices to be assayed, where it receives the impression of a lion rampant, the arms of the duke of Cornwall, and which is necessary to make it saleable. Grain tin is found in small particles, in what is called the *stream tin ore*. It appears to have been washed from its original bed in remote ages. This kind of tin owes its superiority not only to the purity of the ore, but to the care with which it is washed and refined. Tin when taken to be stamped pays a duty of four shillings per hundred weight to the duke. From hence a vast income accrues to the prince of Wales. For a particular account of the management of the Cornish tin-mines, consult the sixth volume of Maurice's Indian Antiquities, and Mr. John Taylor's communications in the Philosophical Magazine.

XXXI.

Wine Tests.

We are told that fraudulent wine-merchants have sweetened their wines and ciders by the addition of lead. Dr. Watson relates that it was at one time a common practice at Paris. He directs how it may be detected. See his Chemical Essays, vol. iii. page 369. Methods of detecting this and other adulterations of wine may be seen in Dr. Willich's Lectures on Diet and Regimen, pages 357 to 362. The following is easy of application, and will be found effectual:—Equal parts of oyster shells and sulphur may be heated together, kept in a white heat for 15 minutes, and, when cold, mixed with an equal quantity of cream of tartar: these are put into a strong bottle with common water to boil for an hour; and then decanted into ounce phials, adding 20 drops of muriatic acid to each. This liquor precipitates the least quantities of lead, copper, &c. from wines in a very sensible black precipitate. As iron might accidentally be contained in the wine, the muriatic acid is added to prevent its precipitation, and its being mistaken for the precipitate of lead. See pages 327—330.

* Dr. Thomson, vol. i. 177.

XXXII.

Native Copper.

ass of *native* copper has been found in a valley in the
s 2666 pounds weight. The description of it in the Me-
of the Royal Academy of Sciences of Lisbon is said to be
nteresting, as the largest specimen of native copper that
er been found before this weighs only ten pounds. Ap-
to Monthly Review, vol. xxvii. N. S. 551. The places
native copper is generally found are Siberia, Sweden,
ry, and some parts of France.

XXXIII.

Of Iron.

re are several ways of analysing iron ores. An easy
l has been suggested by Dr. Higgins; viz. by noting the
y of hydrogen gas that is given out, by treating them
he usual mixture of sulphuric acid and water. This
l will give, with very little trouble, a good comparative
s. One part sulphuric acid to eight parts water is the
proportion for use.

Of all the metals this is certainly the most important, especially as it possesses so many properties, exists in so many different states, and is capable of being applied to such a variety of useful purposes.

"Hail, adamantine steel! magnetic lord!
King of the prow, the ploughshare, and the sword!
True to the pole, by thee the pilot guides
His steady helm amid the struggling tides,
Braves with broad sail the immeasurable sea,
Cleaves the dark air, and asks no star but thee."

DARWIN.

XXXIV.

Of the Iron Manufactories.

Some idea of the extent and importance of the iron trade (see page 315) may be conceived from the following account of the iron works in South Wales:—"Merthyr Tydvill was a very inconsiderable village till the year 1755, when the late Mr. Bacon obtained a lease of the iron and coal-mines of a district at least eight miles long, and four wide, for 99 years. Since then these mines have been leased by him to four distinct companies, and produce to the heirs of Mr. Bacon a clear annual income of ten thousand pounds. The part occupied by Mr. Crawshay contains now the largest set of iron works in the kingdom. He constantly employs more than two thousand workmen, and pays *weekly* for wages, coal and other expenses of the works, twenty-five thousand pounds. The number of smelting furnaces belonging to the different companies at Merthyr is about sixteen. Around each of these furnaces are erected forges and rolling-mills, for converting pig into plate and bar iron. These works have conferred so much importance on the neighbourhood, that the obscure village of Merthyr Tydvill has become the largest town in Wales, and contains more than twelve thousand inhabitants."—Abridged from *Malkin's Scenery, &c. of South Wales.*

XXXV.

Of the Diamond.

"It will no doubt be demanded how it happens that pure carbon or diamond is so scarce, while its compounds in different states are so abundantly dispersed? To dispel the astonishment of those who might consider this a ground of distrust, I shall remind them that the aluminous earth is likewise one of the commonest substances, though the adamantine spar, no less rare than the diamond, is nevertheless alumine: that iron exists every

under every form, excepting in the state of purity, and existence of *native* iron is still doubtful. The wonder ng the diamond consists only in the opposition between d our opinions: it disappears in proportion as we dis- ad appropriate the powers of nature to produce the same

See page 288.

XXXVI.

Of the Absorption of Caloric.

Black heated a quantity of water in a strong phial, closely till its temperature rose ten degrees above 212°, its usual point. On drawing the cork quickly, a small portion of shed out in vapour, and the temperature of the remain- l sunk instantly to 212°. Ten degrees of caloric, there- d been absorbed by the quantity of vapour that escaped. tt, by heating water under the pressure of a strong iron raised its temperature to 400°; yet still when the pressure moved, only part of the water was converted into vapour, temperature of this vapour, as well as that of the remain- l, was no more than 212°. There were therefore 188 of caloric absorbed in an instant, by the formation of the which had no effect on the thermometer.

new foliage, and which is itself destined to undergo similar putrefaction and renovation to the end of time.

"Link after link the vital chain extends,
And the long line of BEING never ends."

How insignificant do the most stupendous works of art appear, when compared with the beautiful simplicity of these masterpieces of Nature! See page 290.

XXXVIII.

Of the Caloric of Combustion.

Dr. Crawford determined by numerous experiments, that the evolution of caloric which attends combustion is owing to *change of capacity*. He found that the capacity of oxygen gas for caloric is much greater than the capacities of combustible bodies; he likewise ascertained that the capacity of the compound resulting from the combustion is always much less than that of the oxygen gas: it is therefore evident, that caloric *must* be rendered sensible during combustion, and that it is from the oxygen gas, and not from the combustible, that it must be evolved.

XXXIX.

Of Pit-coal.

Dr. Darwin was of opinion, that our pit-coal has all been sublimed more or less from the clay with which it was at first formed, in the decomposition of morasses.* Naphtha, which is found in great abundance in Persia, is as fluid and transparent as water; but when exposed to the air it becomes yellow, and then brown; its consistence is increased, and it passes into *petroleum*. Petroleum is found native in many countries, and by an exposure to the air becomes *mineral tar*. Mineral tar is also found native, which by exposure to the air passes into *mineral pitch* and *maltha*. By further induration this passes into *asphaltum*, which substance is likewise found native in many parts of the world. Common coal is a composition of some of these bitumens and charcoal. The French jet and the English cannel

* Note, page 90, part i. of his Botanic Garden.

both so hard that they are susceptible of polish, and uently wrought into trinkets. See Notes, pages 269).

XL.

Of the Glow-worm.

glow-worm is the wingless *female* of a beetle insect. le is of a dusky hue, without much beauty or peculiarity ings. The female is more like the larva or grub of a han a perfect full-grown insect. The light, which is of ful sulphur colour, proceeds from the three last rings of . See page 386. From the circumstance of the male winged animal, and the female not, it was necessary ne contrivance should be had recourse to for directing bler to his sedentary mate. What more beautiful, and me time sufficient guide could possibly be contrived, s self-lighted hymeneal torch ?"

" Thine is an unobtrusive blaze,
Content in lowly shades to shine ;
How much I wish, while yet I gaze,
To make thy modest merit mine !"

MRS. OPIE.

parent and amorphous, it forms CORNELIAN; when stained with dark coloured spots or arborizations, MOCHO STONES. The OPAL, the PITCH STONE, and the HYALITE are fossils of the same family. JASPER is a siliceous fossil which exhibits great variety in its appearances. It is generally composed of about 60 parts silex, 30 of alumine, and 10 parts of potass, magnesia, and oxide of iron. Its colours are various, and it is susceptible of a high polish. Its specific gravity is from 2.3 to 2.7. Where it is composed of alternate broad stripes or layers of different colours, it is termed RIBBAND JASPER: the variety which is found in spheroidal masses, and exhibits various colours or shades of the same colour in concentric and alternating stripes or layers, is termed EGYPTIAN PEBBLE.

PUDDING STONE is a collection of rounded pebbles cemented together by siliceous matter intermixed with iron. It takes a fine polish, and possesses a considerable degree of hardness.

GARNET is of a deep red colour, sometimes varying to brown, black, or violet. Its specific gravity is from 4 to 4.3. The common red kind consists of silex 48, alumine 30, lime 11, iron 10. LEUCITE, or white garnet, is generally in small opaque crystals, and contains 20 per cent. of potass.

LAPIS LAZULI is a stone of a rich blue colour, having little lustre, but susceptible of a fine polish. Its specific gravity is 2.7; its colour is occasioned by a blue sulphuret of iron. It occurs massive, and is so hard as to scratch glass. According to Klaproth it is composed of 46 silex, 14.5 of argil, 28 of carbonate of lime, 8.5 of sulphate of lime, 3 of oxide of iron, and 2 of water. That beautiful fine pigment known by the name of ultramarine is made from this fossil.

LXII.

Of Aluminous Fossils.

The aluminous fossils differ from the aluminous earths in having the hardness of stones, and in not falling into powder when immersed in water. The principal are the following.

CORUNDUM, or adamantine spar, is distinguished from every other stone, by its great hardness, which is such that it is used for polishing even the diamond. Its specific gravity is from 3.9 to 4.1. It consists of 84 to 89 of alumine, 5 or 6 of silex, and from 1 to 7 of oxide of iron.

LEUCHALITE, or LEPIDOLITE, is of a violet blue or purple colour, and, when in thin laminæ, of a silvery white; it has a pearly lustre with a slight transparency. Its specific gravity

is 2.8. It is composed of about 55 parts of silex, 38 o
mine, 4 of potass, and 1 of iron and manganese, with 2 o
water.

CYANITE is of a blueish gray colour, with streaks of deep
Its specific gravity is 3.5. It consists of 66 alumine, 13
nesia, 12 silex, 1 lime, and 5 of iron.

HORNBLENDE. Common hornblende is amorphous,
gray or black colour, and possesses considerable hardness
specific gravity is from 3.6 to 3.8. By heat it may be fuse
glass. According to Kirwan, it consists of silex 37, alumi
carbonate of magnesia 16, carbonate of lime 2, and oxi
iron 23.

TRAP. Under this name are comprehended several va
of stones, which agree in their general characters. It is
in large masses, of a gray, blue, or purplish black colour,
tute of lustre or transparency, and presenting generally a t
composed of granular concretions. WHINSTONE is a v
of this fossil.

BASALTES is a similar fossil; but it has a greater sp
gravity than trap, and is always in large masses of a r
form, generally columnar. According to Klaproth it is
posed of 44.5 silex, 17 alumine, 20 oxide of iron, 9.5 of
2.6 soda, and 6 manganese and water. See page 236, an
ditional Notes, No. 14.

SLATE, the last of the aluminous stones, is of a blue or gr
colour, with little lustre and scarcely any transparency;
composed of alumine, silex, lime, magnesia, and oxide of
united in various proportions, in the different specimens.

XLIII.

Of Magnesian Fossils.

The magnesian fossils are distinguished by a peculiar so
and unctuosity, and by being destitute of the hardness and
bility of the siliceous genus.

CHLORITE is a fossil of a green colour and scaly texture,
out lustre. It occurs both amorphous and crystallized, and
sists of magnesia 39, silex, 42, alumine 6, lime 1.5, iron 10
water 1.5.

TALC has a plated texture, the lamellæ being easily sepa
from each other. These lamellæ are flexible, but not el
their colour is a greenish white, with sometimes a tinge of
The fossil consists of 50 silex, 44 magnesia, and 6 of alu
Its specific gravity is 2.7 to 2.8.

STEATITE, or rock soap, exists in various states of indura
Its specific gravity is 2.6. It always feels soft and greasy

a white, yellowish, or greenish gray colour; often spotted or veined; with little lustre or transparency. It is composed of silex, magnesia, alumine, oxide of iron, and water, in various proportions.

SERPENTINE is of a dark green colour, sometimes red or blueish gray, with spots or veins of other colours, through its substance; without lustre, but susceptible of a fine polish. Its specific gravity is 2.6. It is always found amorphous. It is composed of silex 45, magnesia 33, iron 14, carbonate of lime 6, alumine and water 2.

ASBESTUS is distinguished by its fibrous or striated texture. Its colour is green, greenish gray, or yellowish gray. It does not effervesce with acids. Its specific gravity is 2.5. Its component parts vary, consisting of silex, magnesia, iron, and alumine; the silex being generally in the largest proportion. See page 118.

AMIANTHUS is a similar fossil, differing from asbestus in its filaments being more separated and flexible. According to Mr. Chenevix it is composed of silex 59, magnesia 25, lime 9, alumine 3, iron 2.

MOUNTAIN CORK is of a white, yellowish, gray, or brown colour; without lustre or transparency; and so light as to swim upon water: its specific gravity being from 0.68 to 0.99. It consists of silex 56, carbonate of magnesia 26, alumine 2, carbonate of lime 13, and oxide of iron 3.

JADE is of a dark green colour, verging often to blue. From its supposed medical virtues it was formerly called NEPHRITIC STONE. Its specific gravity is 2.9. It consists of silex 47, carbonate of magnesia 32, alumine 4, lime 2, and iron 9. The inhabitants of New Zealand make their hatchets and other edge tools with this stone.

BORACITE occurs in small cubic crystals, of a grayish white colour. It is a compound of magnesia and lime with boracic acid; its proportions being 13 of magnesia, 11 of lime, and 68 of acid, with 1 of silex, 1 of alumine, and 1 of iron. Its specific gravity is 2.565. This fossil has been found near Luneberg seated in a bed of sulphate of lime.

XLIV.

Of Calcareous Fossils.

GYPSUM, or Plaster of Paris, exists native in considerable quantity, and forms immense strata in various parts of the world. Its specific gravity is 2.3. It consists of 32 parts of lime, 46 of sulphuric acid, and 22 of water. Some of the varieties contain carbonate of lime, alumine, iron, and silex.

Fluor spar is found both amorphous and crystallized is susceptible of a fine polish. Its specific gravity is abou Its colours are very various, and in general beautiful. A ing to Scheele it is composed of 57 of lime, 16 of fluori and 27 of water.

Apatite, which is a phosphate of lime, occurs crysta and amorphous. Its specific gravity is 3.2. Its colour is green, red, or purple. It consists of 55 of lime, and 45 of phoric acid.

Calcareous spar is crystallized, amorphous, and stala Its specific gravity is 2.7. The crystals are distinguish their laminated texture, and by their fragments being rho dal and possessing the property of *double refraction*.* They often the transparency of the siliceous crystals, but want hardness, being easily scratched with a knife. They con 55 lime, 34 carbonic acid, and 11 of water. *Amorphous* reous spar has less transparency and lustre, and its fractur sents distinct granular concretions.

The *Stalactites* are distinguished by their fibrous or s texture, and their peculiar shapes; being formed at the t caverns, by water filtering through the roof, loaded with c ate of lime. According to Bergman they are composed parts lime, 34 of carbonic acid, and 2 of water. Their sp gravity is 2.7. The *Stalagmites* are similar depositions, f

XLV.

Vegetable Poison.

In the royal cabinet of Louis the Sixteenth, at Paris, there were arrows whose points were steeped in the juice of so venomous a plant, that, though exposed to the air for many years, they will by the slightest puncture in a few minutes destroy the stoutest animal that exists. The blood of the victim, trifling as may be the wound, instantly congeals; but, if a small quantity of sugar be immediately swallowed by him, the circulation is as quickly restored.* See page 6.

"Nature, compell'd by a superior cause,
Now breaks her own eternal laws,
Now *seems* to break them, and obeys
Her sovereign King in different ways."

WATTS'S LYRICS.

XLVI.

Predatory Insects.

Having already considered (pages 55 and 66) several of those means by which the atmosphere is regularly renovated, it may not be amiss to remark, that the Deity has also provided an innumerable multitude of predatory insects to assist in the accomplishment of the same purpose. These remove the noxious matter that otherwise might rest upon the surface of the earth; and they convert to their own support, even such excrementitious substances as, by the exhalation of their putrid miasmata, would in time totally destroy the whole animal creation. —Is it possible for an unprejudiced mind to avoid being charmed with this beautiful economy of nature; or for those sapient philosophers to escape our pity, who *endeavour* to persuade themselves, that to chance only they are indebted for all these congruities?

"To me, the laurel'd wreath that murder rears,
Blood-nurs'd, and water'd by the widow's tears,
Seems not so foul, so tainted, and so dread,
As waves the nightshade round the sceptic head."

CAMPBELL.

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* St. Pierre's Studies of Nature, vol. i. 13

XLVII.

Of some of the Effects of Respiration.

oxygen of the atmosphere deprives the blood of its ex-
carbon and hydrogen: with the first it forms carbonic
nd with the latter water; and these are thrown from the
n the act of respiration. As carbonic acid has the pro-
of sweetening putrid substances, by uniting chemically
trid vapour, may it not operate in this way with regard
putrid exhalations from the lungs, and render the breath
e persons inoffensive, which would otherwise be intolera-
id and pestilential?* See page 62.

XLVIII.

Of Snow.

ure has furnished snow with the power of absorbing and
ning with a large portion of oxygen, which gives it its
ing property. The snow melting and penetrating into the
d earth communicates to it oxygen, and this oxygen pro-
the germination of seeds. The carbon of the earth com-

with wood-ashes and lime, and the scum taken off. This boiling with ashes and lime is repeated in three other boilers, which process converts it into syrup. It is then strongly boiled with lime and alum, and when sufficiently concentrated is poured into hogsheads pierced at the bottom with many holes, to let off the molasses, which will not crystallize. These holes are afterwards stopped with canes, as we see them when imported. The sugar, as it cools, becomes solid in the casks, and is called *muscovado* sugar. It afterwards undergoes several refinings in order to form it into loaf sugar. See Thomson's Fourcroy, 1800, vol. iii. 116.

It should be remembered that oxygen is absolutely necessary for the formation of sugar, which is a vegetable oxide. If it were deprived of the greater part of this oxygen, it would lose its sweetness, and would be no longer sugar, but a singular kind of substance possessing properties more analogous to gum than sugar. Mr. Cruickshank has effected this change on sugar by means of phosphuret of lime, which has a very strong attraction for oxygen; though he was not able to reproduce sugar by the union of gum with oxygen. See pages 140 and 287. See also an account of these experiments in Dr. Rollo's Treatise on Diabetes.

A variety of new experiments on the nature of sugar may be seen in a Paper, which, in the summer of 1808, I read before a Committee of the House of Commons, and which was afterwards ordered to be printed in their Report, for the use of the members. Those persons who have no means of seeing the Reports of the House, may find an abstract of this paper in the Philosophical Magazine for September, 1808.

L.

Coke Ovens.

As the success of several manufactures depends on the procuring good coke, (see note, page 432,) I feel pleasure in having it in my power to furnish a description of the kind of oven made use of in the north of England for coking the refuse small coal, which, before the adoption of this method, was entirely useless.

At the Duke of Norfolk's colliery near Sheffield, several of these ovens are built on the side of a hill, occupying spaces formed within the bank. Each oven is a circular building, 10 feet in diameter within, and the floor laid with common brick set edgeways. The wall of the oven rises 19 inches perpendicular above the floor, and the whole is then covered with a brick

arch which rises 3 feet 5 inches more, forming nearly a cone, whose base is 10 feet, and whose apex is 2 feet, if measured within. This opening of 2 feet at the top, is left for the convenience of supplying the oven with coal, and to serve as a chimney during the process. The whole height of the building from the floor is five feet, and the wall, which is 18 inches in thickness, is built with good brick, and closely laid, that no air may get in through any part of the work.

The floor is elevated three feet above the ground, for the convenience of placing a carriage under the door-way to receive the coke as it is raked from the oven. When the oven is thus finished, a strong perpendicular wall of common unhewn stone is thrown round it, of about 20 inches in thickness, and carried up the whole height of the oven, forming a complete square. The four corners between the circular building and these outward walls, are then filled with soil or rubbish, and well rammed to give greater firmness to the work, and the more effectually to exclude atmospheric air.

When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus:—Small refuse coal is thrown in at the circular opening on the top, sufficient to fill the oven up to the springing of the arch; it is then levelled with an iron rake, and the door-way built up with loose bricks. The heat which the oven acquires in the former operation is always sufficient of itself to light up the new charge: the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the door-way. In two or three hours the combustion gets to such a height, that they find it necessary to check the influx of atmospheric air: the door-way is therefore now plastered up with a mixture of wet soil and sand, except the *top* row of bricks, which is left unplastered all night. Next morning (when the charge has been in 24 hours) this is completely closed also; but the chimney remains open till the flame is gone, which is generally quite off in 12 hours more; a few loose stones are then laid on the top of the chimney, and closely covered up with a thick bed of sand or earth. All connexion with the atmosphere is now cut off, and in this situation the whole remains for 12 hours, to complete the operation. The door-way is then opened, and the cokes are raked out into wheelbarrows, to be carted away. The whole takes up 48 hours; and as soon as the cokes are removed, the ovens are again filled with coal for another burning. About 2 tons of coal are put in for each charge. These cokes are ponderous, extremely hard, of a light gray colour, and shine with metallic lustre. They are used in those manufactures that require an intense heat.

When coke is required to be more of the nature of charcoal, the process is conducted in a different manner. The small coal is thrown into a large receptacle similar to a baker's oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals, the disengagement of which is promoted by frequently stirring with a long iron rake. The coke from these ovens, though made with the same kind of coal, is very different from that produced by the former operation: this being intensely black, very porous, and as light as pumice-stone. I am indebted to Mr. Curr, steward to his Grace the Duke of Norfolk, for these particulars, who very politely attended me through the works in the year 1802, and assisted me in taking the necessary measurements, &c.

LI.

Of the Uses of Diamond.

The lapidaries employ a considerable quantity of diamond in powder, which they use with steel instruments, to divide pebbles and precious stones. The small pieces of diamond of which the powder is made, are worth 20 shillings a carat. The use of the diamond in this way is very extensive. Had nature withheld the diamond,—the pebble, the agate, and a variety of other stones, would have been of little value, as no other substance is hard enough to operate upon them. In this way rock crystal from Brazil is divided into leaves, and ground and polished with diamond dust for spectacles, and other optical instruments. See page 267.

LII.

Of the Effect of Oxygen upon Colours.

Several of the effects of oxygen have been mentioned in different parts of this work: but its action on colouring substances has not been noticed, though it is various and striking. When woollen cloths are taken out of an indigo vat, they are of a green colour: but they are scarcely exposed to the atmospheric air for one minute, before they imbibe a sufficient portion of oxygen to change that colour to a deep blue. In like manner the whelk (the *buccinum* of Linnæus,) which is used to dye purple, undergoes a change equally extraordinary. The liquor, though naturally yellow, becomes oxidized by exposure to the sun and air, passes through various shades of yellow, green, crimson, &c.

and at length becomes purple. A good *black* cannot be given to cloth without frequent exposure to the air. Light has a great affinity for oxygen: hence cloths frequently fade and lose their colours by the abstraction of oxygen. That part of the furniture of a bed which has been exposed to the sun will often be entirely faded, while those parts which have not been so exposed will retain their original colours. This probably arises from the loss of oxygen, and that the oxygen which existed in a solid form is rendered aëriform by the rays of the sun, and goes off in the state of oxygen gas. See page 389.

LIII.

Of the Gases emitted in Respiration.

Having shown that sheet of the work which contains page 66 to a friend, an ingenious chemist, he suggested that those remarks on the *levity* of nitrogen gas evolved from the lungs in respiration would have more force, were I to contrast this character with the superior specific gravity of carbonic acid gas, which is ejected at the same instant. For during that *remarkable* interval that always occurs in breathing, there is sufficient time allowed for these noxious fluids to separate; the first to ascend, while the other preponderates, leaving a space for a fresh current of uncontaminated atmospheric air. Thus every thing is prepared without any care or forethought of ours for a new inspiration.

> "The air inhal'd is not the gas
> That from a thousand lungs reeks back to thine
> Sated with exhalations rank and fell,
> Which, drunk, would poison the balsamic blood,
> And rouse the heart to ev'ry fever's rage—
> But air that trembling floats from hill to hill,
> From vale to mountain, with incessant change
> Of purest element."

DR. ARMSTRONG.

LIV.

Of Lutes.

Glazier's putty is a very good lute for all common purposes, but it is necessary that the whiting be made thoroughly dry before it be mixed with the oil. Linseed oil and sifted slaked lime, well mixed, and made thoroughly plastic, form an excel-

lent coating for retorts: if made thicker, this mixture is an impenetrable luting, that is not liable to crack.

Dr. Black recommends a mixture of four parts sand, and one of clay, except where it is to be exposed to an intense heat, and in such situations to use six parts of sand to one of clay.

For *fire*-lute Mr. Watt directs the use of porcelain clay from Cornwall (not pipe-clay,) to be pounded small, and mixed up to the consistence of thick paint, with a solution of two ounces of borax in a pint of hot water. For want of this peculiar kind of clay, slaked quick-lime, mixed up in the same manner, may be used. This may be kept ready mixed in a covered vessel. For *cold*-lute he directs to take equal parts by measure of the above clay and wheat flour, and to mix them to a proper consistence with cold water. This is more tenacious than his fire-lute, but does not keep so well.

A very excellent lute for many purposes may be made by beating up an egg, both the white and the yolk, with half its weight of quick-lime in powder. This lute is to be put upon a piece of linen, and applied as usual. It dries slowly, but becomes very compact, and acquires great hardness.

A mixture of martial pyrites and muriate of ammonia forms a good lute for stopping the cracks in iron utensils; but the following artificial compound is preferred, on account of the exact proportions of the ingredients being more easily ascertained. To two pounds of iron turnings or filings, add one ounce of sal ammoniac, and one ounce of flour sulphur; blend the mixture with water till the whole is of a proper consistence, and use it fresh. This lute is employed by engineers to stop the joints of steam engines, and other machinery.

Just as this sheet was going to press, I received a letter from an intelligent stranger, informing me that a mixture of salt and whiting, properly kneaded with water, makes a very hard and durable lute for many purposes, particularly for securing the joints of the apparatus which is employed for the production of carburetted hydrogen gas.

LV.

Of the extreme Hardness of Ice in some Countries.

The following narration will show the solidity that water is capable of acquiring when divested of a large portion of its caloric:—During the severe winter of 1740, a palace of ice, fifty-two feet long, sixteen wide, and twenty high, was built at Petersburgh, according to the most elegant rules of art. The river Neva afforded the ice, which was from two to three feet

blocks of which were cut, and embellished with various
ents. When built up, the different parts were coloured
inkling them over with water of various tints. Six can-
nade of and mounted with ice, with wheels of the same
, were placed before the palace; and a hempen bullet
iven by one of these cannon, in the presence of the whole
through a board two inches thick, at the distance of sixty

"No forest fell,
mperial mistress of the fur-clad Russ,
When thou wouldst build;—no quarry sent its stores
T' enrich thy walls; but thou didst hew the floods,
nd make thy marble of the glassy wave.
ilently as a dream the fabric rose;
ce upon ice the well adjusted parts
Were soon conjoin'd; nor other cement ask'd
Than water interfus'd to make them one.
amps gracefully dispos'd, and of all hues,
llumin'd every side. Long wavy wreaths
)f flowers, that fear'd no enemy but warmth,
Blush'd on the pannels, which were once a stream,
And soon to slide into a stream again."

COWPER.

of priming contains only an eighth of a grain of oxymuriate of potass, that alone makes a very loud report: and the principle of the lock is such, that it can never possibly miss fire. This effect is entirely attributable to the large portion of oxygen, which is condensed in this very singular salt.

LVII.

Of the Efficacy of Water in Vegetation.

That vegetables will grow in woollen cloth, moss, and in other insoluble media, besides soils, provided they be supplied with water, has been repeatedly shown since the days of Van Helmont and Boyle: but the experiments of a modern author, from their apparent correctness, seem more highly interesting and conclusive.

Seeds of various plants were sown in pure river-sand, in litharge, in flowers of sulphur, and even among metal, or common leaden shot; and in every instance nothing employed for their nourishment but *distilled water*. The plants flowered, and passed through all the usual gradations of growth to perfect maturity. The author then proceeded to gather the entire produce, the roots, stems, leaves, pods, seeds, &c. These were accurately weighed, dried, and again weighed, then submitted to distillation, incineration, lixiviation, and the other ordinary means used in a careful analysis. Thus he obtained from these vegetables all the materials peculiar to each individual species, precisely as if it had been cultivated in a natural soil,—viz. the various earths, the alkalies, acids, metals, carbon, sulphur, phosphorus, nitrogen, &c. He concludes this very important paper nearly in these extraordinary words: "*Oxygen* and *hydrogen*, with the assistance of solar light, appear to be the only elementary substances employed in the constitution of the whole universe: and Nature, in her simple progress, works the most infinitely diversified effects by the slightest modifications in the means she employs." See "*Recherches sur la Force assimilatrice dans les Végétaux*," par M. Henri Braconnot, *Annales de Chimie*, Fevrier et Mars, 1808.

LVIII.

Of the Agencies of Galvanism.

The experiments of Sir Humphry Davy, published in the first part of the Philosophical Transactions for 1807, have thrown

considerable light on the agencies of electricity and galvanism. See note,† page 396.

First. In opposition to the assertions of Pacchiani and others, he has demonstrated that muriatic acid is not produced in water by the agency of galvanism, but that water "chemically pure is decomposed into gaseous matter alone, into oxygen and hydrogen."

Secondly. By the agency of galvanism he decomposed sulphate of lime, sulphate of strontian, fluate of lime, and other solid bodies, insoluble, or difficultly soluble in water. In each case the earth was found in one vessel and the pure acid in the other. Even glass was decomposed, and part of its alkali exhibited entire. Sulphuric, muriatic, nitric, and phosphoric salts were decomposed with more rapidity; the acids in a certain time collected in the tube containing the positive wire, and the alkalies and earths in that containing the negative.

Thirdly. He connected a small cup, made with sulphate of lime, with a cup of agate, by a piece of asbestus; and, filling both with purified water, made a platina wire in the cup of sulphate of lime transmit the electricity from a power of 100 plates; a wire in the agate cup received it. In about four hours a strong solution of lime was found in the agate cup, and sulphuric acid in the cup of sulphate of lime. By reversing the order, and carrying on the process for a similar time, the sulphuric acid appeared in the agate cup, and the solution of lime on the opposite side.

Fourthly. Acid and alkaline substances passed through water containing vegetable colours, without affecting them; and the usual chemical affinities were so far destroyed or suspended by the agency of galvanism, that sulphuric acid was passed through a solution of ammonia without combining with it. In like manner the alkalies and earths were transmitted through acids, without combination.

From these and similar results, it appears that "hydrogen, the alkaline substances, the metals, and certain metallic oxides, are *attracted* by negatively electrified metallic surfaces, and *repelled* by positively electrified metallic surfaces; and contrariwise, that oxygen and acid substances are attracted by positively electrified metallic surfaces, and repelled by negatively electrified metallic surfaces; and these attractive and repulsive forces are sufficiently energetic to destroy or suspend the usual operation of elective affinity." Sir H. Davy concludes this most important paper by suggesting that this new method of decomposition may, probably, be introduced with advantage into some manufactures; and imagines, that he shall be able to refer several

natural phenomena to this source, which have been hitherto inexplicable.

For an account of his experiments on the alkalies, See Additional Notes, No. 67.

LIX.

Of the Origin of Caloric.

The author of a modern work, entitled "Physical and Metaphysical Inquiries," imagines that caloric is *not* transmitted from the sun; but that it is a subtile fluid, originally belonging to our earth. The arguments by which he supports this opinion appear to me to have great weight; but I must refer the reader to the work itself, and content myself with merely copying the conclusion he draws from these premises: "This view of the nature of caloric," says he, "is more correspondent with the general character of matter, than those generally entertained. It still represents the sun as the great agent in the production of heat, without supposing it to be an enormous mass of fire. We have only to consider the sun as the great storehouse of light; a power, indeed, the most active in nature, but no ways destructive. It shows that light produces heat merely by exciting an insensible action betwixt caloric and the particles of matter contained in bodies. It accounts for the want of heat in the upper regions of the atmosphere by the want of sufficient matter to produce the action of caloric. It destroys the absurd opinion concerning transmitted and conducted heat, so contrary to the invariable characters of all the material powers. It shows that caloric is not an exception to all the other kinds of matter, but that, like its fellows, it exists in other characters besides that of heat. It enables us to solve the great difficulty concerning the distribution of heat among the different planetary bodies; for, according to this view, those nearest the sun may have no more than those at the most remote distance. We have only to suppose the quantity of caloric to be proportioned to the distance; and if a *small* quantity exists in the planet Mercury, no more heat may be excited than is done by a *larger* quantity in Saturn."

Mr. Bell, in his System of Anatomy, denies that animal heat is preserved entirely by the inspiration of atmospheric air, and advances a new theory, which he supports by several striking facts. See Bell's Anat. vol. ii. article *Blood*.

e summer solstice, in the northernmost parts of our island, descends very little below the horizon, and there is no e night, for by the twilight a person may distinctly read night. Near the poles of our world, where one day and ght divide the year, there are some weeks of continued t, and the sun is several days visible before he actually ove, and after he has sunk beneath the horizon. See page 44 of this volume.

LXV.

Of Dyers' Aquafortis.

s article is used for dissolving tin, to form a mordant for some of the most valuable colours on woollen cloths. In ying this acid, the dyers in the metropolis generally pro- hus: A carboy of aquafortis is measured out into a large n pan, with from one to two quarts of water for every gal- the acid, and the whole is well mixed by stirring it with ıg wooden spatula.

posing single aquafortis be used, the quantity of water

of their forefathers. This shows of what importance it is to determine, by chemical analysis, the nature of every substance which passes under the miner's observation. See Note, page 311.

LXIII.

Theory of Rain.

Since the publication of the third edition of the Chemical Catechism, I have found that the idea of the formation of clouds by the agency of electricity was mentioned by Volta, and also by Dr. Franklin some years ago. See Franklin's Works, London edition, 1806, vol i. 207 and following pages. For directions to some of the best papers on this subject, see the Notes at page 39 of this volume.

LXIV.

Of Twilight.

Whenever the rays of light pass from one medium to another, they do not afterwards proceed in the same straight lines, but are refracted or bent by the attraction of the denser medium, and proceed as though they had been propagated from another point. If the rays of light pass from a dense to a rarer medium, they are refracted, and in their bending they recede *from* the perpendicular; but, when they come from a rarer into a denser medium, as out of a vacuum into air, or out of air into water, they are refracted or bent *towards* the perpendicular, that is, towards a line perpendicular to the surface whereon they fall at the point of incidence.* Agreeably to this law of nature, when the sun has sunk below the horizon, or has not yet attained that altitude, so that his rays cannot directly impinge upon our earth, they fall on the atmosphere, which refracts them towards the surface of the earth. This is sufficient to account for the morning dawn and the evening twilight; and for the sun himself appearing a few minutes earlier or later than he really does. The gases that compose our atmosphere

> "With airy lens the scatter'd rays assault,
> And bend the twilight round the dusky vault."

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* See Ferguson's Optics, page 204

ADDITIONAL NOTES.

In making the mixture of aquafortis and water, use as
vater as possible, consistent with the nature of the aqua-
employed.

. In adding the first portion of tin, put in such a quantity
ts action shall soon raise the temperature of the liquor to
100 degrees of Fahrenheit's thermometer. To effect this,
er quantity must be added in winter than in summer.
aquafortis be good, it is best to stir the mixture incessantly
ut five minutes on the first addition of the tin, which has-
id improves the process. Much, however, of the aquafortis,
sold would fire, as it is termed, by this treatment. That
violence of the action would decompose the acid, a great
f which would evaporate and be entirely lost in dense red

h. When the mass has acquired the heat before mentioned,
should be added in such portions only as will preserve it
ut the same temperature.

. Add no salt to the solution till there is an appearance of
oxide collecting at the bottom of the jar. If salt be then
, and stirred with the mixture, this oxide will be taken up
fluid.

h. If the solution of tin be designed for dyeing a perfect

LXVI.

Description of an Apparatus for collecting Gas from Coal, and of its Use in lighting Manufactories and other large Buildings.

Carburetted hydrogen gas, which is now employed in several parts of the kingdom for lighting large buildings, extensive manufactories, mines, &c. is procured in general from common pit coal by means of simple distillation. A variety of apparatus has been invented for this purpose, some of which are very complicated and difficult to be employed, and others are liable to accidents and explosions. The one which appears to me to have the greatest simplicity, and is at the same time perfectly safe in its application, I have procured a drawing of, and have had engraved for this work:—it may be thus described. The retort, within the furnace, is of cast iron; its larger end has an orifice of several inches diameter, for the admission of the coal and the withdrawing of the coke; which orifice is made to shut air-tight by means of an iron plug which screws within it; and to the smaller end of the retort a leaden pipe is affixed, in order to lengthen the apparatus and for the purpose of conveying the gas into the reservoir. This leaden pipe is generally bent into the form of an arch, to occasion more surface, and more effectually to cool the gas before it is delivered into the air-vessel or reservoir. The design of cooling the gas in this way is to occasion it to deposit the

tar which always rises with it from the coal, and remains combined with it till it is somewhat reduced in temperature by passing along the leaden tubes. The two straight tubes passing from the extremities of the arch, and furnished with stop cocks, are designed to carry off this tar into a vessel placed beneath to receive it. If the tube connected with the retort be a few feet in length, a part of the tar will run off by the first pipe, and, in passing along the arched part of the tube, the gas will be further cooled, and more tar will be deposited.* The reservoir or receptacle for the gas is constructed on the principle of a common gasometer, and is made with two cylindrical vessels, one inverted within the other. These vessels may be of tin, or copper, or iron, or wood, as the proprietor chooses; and if economy be his first object, the gasometer may even be made with two common casks, the one inverted within the other. The inner vessel should be suspended from the ceiling of the apartment by a cord or a chain passing over a pulley, and balanced at the other end by a corresponding weight. When the apparatus is thus fixed, water is poured into the outward vessel, so as to fill up the void space between it and the outside of the inner vessel; and the air is then expelled from the latter, by forcing it down to the bottom of the water. The inverted vessel is now become full of water instead of air (the air having passed off at an orifice provided for the purpose, and furnished with a stop cock,) and the whole apparatus is ready for use. After this description, it will be seen by a bare inspection of the drawing, that, whenever the carburetted hydrogen gas is disengaged from the retort, it must rush along the tube, and will rise into the interior of the inverted vessel, which is buoyed up, and continues to rise, so long as the gas continues to accumulate. This suspended and inverted vessel is the only reservoir for the gas, and in this it is safely preserved from escape by means of the water, which is an effectual lute for the apparatus. The quantity of gas in stock is always known by the height of the gasometer, which sinks by the common pressure of the atmosphere, as the gas is used, or withdrawn from beneath it. One of the tubes that rise within the gasometer, is designed to convey the gas into it from the retort, as has been described: the other is intended to convey it to the lamps in the different parts of the apartment. The lamps may be affixed to the main pipe, or smaller pipes may be conducted from thence into other apartments, or from one story of a building to another, as convenience may suggest; for if the gas be lighted it will

* The tube which rises nearly perpendicularly from the retort, and goes into the chimney, is designed to carry off the carbonic acid gas and the water which come over in the beginning of the process, and would injure the carburetted hydrogen gas if suffered to mix with it.

burn with brilliancy, at any orifice, however distant it may be from the place where it is prepared. In extensive manufactories, small brass cocks are generally affixed to every aperture, in order to open or shut the communication with the gasometer, at pleasure, that there may be no waste of gas, and that such a number of lights may be had at all times as the manufactories may require.

Whenever a charge is worked off, the retort is opened and the residuum raked out, which is an excellent coke, equal in value to the coal from which it was produced. Besides the coke, a large quantity of tar is soon collected, very useful in some of the Birmingham manufactures, and employed in making a cement for aqueducts, water-cisterns, &c. &c. According to Mr. Northern of Leeds, who has made some accurate experiments on this subject, 50 ounces of coal produce 6 ounces of liquid matter, oil and tar; 26 ounces of coke, and 18 ounces of gas. Where the apparatus is well constructed, and the buildings required to be lighted are large, the process is very economical Even several hundred pounds are annually saved, in some large establishments, by the use of this gas; particularly in Birmingham, Manchester, and other large manufacturing towns. Some years ago the extensive iron works and the compting-house of Messrs. Bolton and Watt of Soho, near Birmingham, were lighted with it by Mr. William Murdoch of that place, who, as early as the year 1791, was engaged in a series of experiments on carburetted hydrogen gas, and was the first person who employed it in lighting apartments, &c. At the last peace, the whole of the buildings at Soho were illuminated by it in a way which occasioned a very grand and unique appearance. Since then, one of the streets of London has been lighted by the same means, and the effect produced is such as to delight and satisfy every beholder. It is not only more cleanly than the old method, but the light is more beautiful, and far exceeds in intensity any of the lamps hitherto lighted with oil. See note *, page 257.

I have been induced to note these particulars more in detail than the nature of this work seems to justify, because, as we possess coal in abundance in various parts of the kingdom, any advantages that can be given to our manufactures by its means, appear to me to be of great national importance.

LXVII.

Of the Decomposition of the Alkalies.

In the third edition of the Chemical Catechism, page 531, I gave my readers an abridgement from the Philosophical Transactions for 1807, of a very important paper, read by

Sir H. Davy before the Royal Society, on the agencies of galvanism in the decomposition of a variety of alkaline and earthy salts. The experiments which he detailed in that paper were sufficient to produce an alteration in all our former ideas of chemical affinity, as they proved decisively that the formation of all chemical compounds may depend on the electrical state of the materials of which they are composed. Since these he has had the good fortune to make other important discoveries in this ever-fruitful field of research; and in a paper which he read before the Royal Society on the 19th day of November, 1809, he announced that he had succeeded in the decomposition of the fixed alkalies. Having the permission of the author to make use of this very interesting paper, I have now carefully to abridge it, in order to give a correct and succinct account of the important matter which it contains.

In the first attempts which Sir H. Davy made for the decomposition of the fixed alkalies, he entirely failed, in consequence of his having acted upon their aqueous solutions only. He afterwards used potash in the state of igneous fusion, and acted upon it by an electrical power, which was produced from a galvanic battery of 100 plates of 6 inches square, highly charged. Here some brilliant phenomena were produced. A most intense light and a column of flame were exhibited, which seemed to be owing to the development of combustible matter; and when the order was changed, so that the alkali was brought in contact with the negative side of the battery, aëriform globules, which inflamed in the atmosphere, rose through the potash. Being, however, unable to collect the products of decomposition by this means, he had then recourse to pure potash in its usual state, and depended on electricity alone for its fusion, as well as its decomposition.

A small piece of pure potash, moistened a little by the breath, was placed upon an insulated disc of platina, connected with the negative side of a battery consisting of 100 plates of 6 inches and 150 of 4 inches square, in a state of intense activity, and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. Under these circumstances a vivid action soon commenced. The potash began to fuse at both its points of electrization, and small globules having a high metallic lustre, and precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame. These globules, which appear to be metallic, are the basis of potash, that alkali being composed of this peculiar base and oxygen only.

Soda, when acted upon in the same manner, exhibited an analogous result, and these effects equally took place in the atmosphere, and when the alkali was acted upon in the vacuum

of an exhausted receiver; but these globules could not in either case be produced from *crystallized* alkalies. When a globule of the base of potash was exposed to the atmosphere, it immediately attracted oxygen, and a white crust formed upon it, which proved to be pure potash. When the globules were strongly heated and then suspended in oxygen gas, a rapid combustion with a brilliant white flame was produced, and these metallic globules were converted to an alkali, whose weight greatly exceeded that of the combustible matter consumed.

When Sir H. Davy had thus detected the bases of the fixed alkalies, he had considerable difficulty to preserve and confine them, so as to examine their properties and submit them to experiments. He found, however, at length, that in recently distilled naphtha they may be preserved many days, and that their physical properties may be easily examined in the atmosphere, when they are covered by a thin film of it.

The basis of potash, at 60° Fahrenheit, is only imperfectly fluid; at 70° it becomes more fluid; and at 100° its fluidity is perfect, so that different globules may be easily made to run into one. At 50° it becomes a soft and malleable solid, which has the lustre of polished silver; and at about the freezing point of water it becomes harder and brittle, and when broken in fragments exhibits a crystallized texture, of perfect whiteness and high metallic splendour.

To be converted into vapour, it requires a temperature approaching that of the red heat. It is an excellent conductor of heat, and a perfect conductor of electricity.

Resembling the metals in all these properties, it is, however, remarkably different from any of them in specific gravity; for it will not sink in double distilled naphtha, whose specific gravity is only .770, that of water being considered as 1.000. Sir H. Davy has determined by experiment that its specific gravity is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10; so that it is the lightest fluid body known. When this substance is introduced into oxymuriatic acid gas, it burns spontaneously with a bright red light, and muriate of potash is formed. When thrown upon water, it decomposes it with great violence, and instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result. When a globule is placed upon ice, not even the solid form of the two substances can prevent their union; for it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash. When a globule is dropped upon moistened turmeric paper, it instantly burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace. So strong

is the attraction of the basis of potash for oxygen, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified. When thrown into the mineral acids, it inflames and burns on the surface. In sulphuric acid, sulphate of potash is formed; in nitrous acid, nitrous gas is disengaged, and nitrate of potash formed. When brought in contact with a piece of phosphorus, and pressed upon, there is a considerable action: they become fluid together, burn, and produce phosphate of potash. When a globule is made to touch a globule of mercury about twice as large, they combine with considerable heat; the compound is fluid at the temperature of its formation; but when cool it appears as a solid metal, similar in colour to silver. If this compound be exposed to air, it rapidly absorbs oxygen; potash which deliquesces is formed; and in a few minutes the mercury is found pure and unaltered. When a globule of the amalgam is thrown into water, it rapidly decomposes it with a hissing noise, potash is formed, hydrogen disengaged, and the mercury remains free. The basis of potash readily reduces metallic oxides when heated in contact with them. It decomposes common glass by a gentle heat, and at a red heat effects a change even in the purest glass.

In his experiments on soda, Sir H. Davy has discovered that its base, like that of potash, is white, opaque, and has the lustre of silver. The property of welding, which belongs to iron and platina, at a white heat only, is possessed by this substance at common temperatures. It is very similar in its more obvious properties to the base of potash; but it has greater specific gravity, being to that of water nearly as nine to ten, or as .9348 to 1.0000. In oxygen gas it produces a white flame, and sends forth bright sparks, occasioning a very beautiful effect. In oxymuriatic acid gas it burns vividly, with numerous scintillations of a bright red colour. In the quantity of $\frac{1}{20}$th, it renders mercury a fixed solid, of the colour of silver, and forms an alloy with tin. When amalgamated with mercury, the amalgam will combine with other metals. Sir H. Davy tried this with iron and platina, and had reason to believe that these latter metals remain in combination with the mercury, even when deprived of the new substance by exposure to the air.

The whole of the sixth chapter of this very interesting paper is occupied with the detail of several curious and ingenious experiments to ascertain the proportions of the bases and oxygen in the two fixed alkalies; from whence he concludes that 100 parts of potash consist of about 84 basis, and 16 oxygen; and 100 parts of soda consist of about 76 or 77 basis, and 24 or 23 oxygen: or that potash may be considered as consisting of about 6 parts basis, and 1 of oxygen; and soda of 3 basis, and 1 oxygen.

In reply to the question, whether the bases of potash and soda should be called metals, it might be said that they agree with metals in opacity, lustre, malleability, conducting powers as to heat and electricity, and in their qualities of chemical combination. Even their low specific gravity does not appear a sufficient reason for making them a new class; for amongst the metals themselves there are remarkable differences in this respect, platina being nearly four times as heavy as tellurium; and tellurium is not much more than six times as heavy as the basis of soda. Conceiving the bases of the two fixed alkalies to be metals, Sir H. Davy has named one Potasium, and the other Sodium; adopting that termination, which, by common consent, has been applied to other newly discovered metals.

On an examination of the volatile alkali, and after a great number of complex and tedious experiments, Sir H. Davy saw reason to conclude that ammonia contains oxygen as an essential ingredient, and that this cannot well be estimated at less than 7 to 8 parts in the hundred. After making some general remarks on the preceding facts, he suggests the probability that the muriatic, fluoric, and boracic acids, all contain oxygen as one of their constituent principles. The earths of barytes and strontian, as being most analogous to the alkalies, were likewise examined, and both yielded oxygen.

In concluding this very important communication, Sir H. Davy remarks that an immense variety of objects of research is presented in the powers and affinities of the new metals produced from the alkalies. In themselves they will undoubtedly prove powerful agents for analysis; and, having an affinity for oxygen stronger than any other known substances, they may possibly supersede the application of electricity to some of the undecompounded bodies.

In sciences kindred to chemistry, the knowledge of the nature of the alkalies, and the analogies arising in consequence, will open many new views; they may lead to the solution of many problems in geology, and show that agents may have operated in the formation of rocks and earths, which have not hitherto been suspected to exist.

These discoveries will certainly form a new era in the history of chemistry, and render the name of Davy ever dear to those who delight in the investigation of nature.

"Immortal Newton thus with eye sublime
Mark'd the bright periods of revolving time;
Explor'd in Nature's scenes the effect and cause,
And, charm'd, unravell'd all her latent laws."

A more extended view of the connexion between electrical and chemical attraction may be seen in Sir H. Davy's Elements of Chemical Philosophy lately published, vol. i. page 150—173. See also note at page 171 of the foregoing sheets.

CHEMICAL TABLES.

of the Quantities of Acids and Bases which mutually tralize each other: calculated by Berthollet from the Tables published by Richter.

Bases.		Acids.	
ine	525	Fluoric	427
esia	615	Carbonic	577
onia	672	Sebacic	706
	793	Muriatic	712
	859	Oxalic	755
tian	1329	Phosphoric	979
s	1605	Formic	988
es	2222	Sulphuric	1000
		Succinic	1209
		Nitric	1405
		Acetic	1480

Table of the Affinities of sundry Bases for four of the Acids, according to their Intensity.

I. *Sulphuric Acid.*

	Intensity.
Ammonia	383
Magnesia	171
Lime	143
Soda	127
Potass	82
Strontian	72
Barytes	50

II. *Nitric Acid.*

	Intensity.
Ammonia	245
Magnesia	209
Lime	179
Soda	136
Potass	85
Strontian	85
Barytes	56

III. *Muriatic Acid.*

	Intensity.
Ammonia	171
Magnesia	111
Lime	84
Soda	73
Potass	56
Strontian	41
Barytes	31

IV. *Carbonic Acid.*

	Intensity.
Ammonia	unknown
Magnesia	200
Lime	81
Soda	66
Potass	105
Strontian	43
Barytes	28

A Table of the real Specific Gravity of Solutions as indicated by Baumé's Areometer for Salts.—Drawn up by Robert Bingley, Esq. of the Tower of London.

Spec. Grav.	Degrees of Areometer.	Spec. Grav.	Degrees of Areometer.
1,435	46	1,300	34
1,416	43	1,283	32
1,400	42	1,275	31
1,383	41	1,267	30
1,367	40	1,250	29
1,358	39	1,233	28
1,350	38	1,216	26
1,342	37	1,167	20
1,333	36	1,150	18
1,312	35		

'able of the boiling Point of sundry Liquids, &c.

- -	98°	Phosphorus -	554°
ammonia -	140	Oil of turpentine	560
ol - -	176	Sulphur -	570
- -	212	Sulphuric acid -	546
e of lime -	230	Linseed oil -	600
acid -	248	Mercury -	660

of the Quantity of real Acid taken up by Alkalies and Earths.—By Mr. Kirwan.

00 Parts.	Sulphuric	Nitric.	Muriatic.	Carbonic.
ass -	82,48	84,96	56,30	105
la -	127,68	135,71	73,41	66,80
monia -	383,80	247,82	171	Variable
ytes -	50	56	31,80	282

TABLE OF BAUMÉ'S HYDROMETERS.

Baumé's Hydrometer for Vinous Spirits, or other Liquids lighter than Water. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
10	= 1·000	21	= —.922	32	= —.856
11	—·990	22	—·915	33	—·857
12	—·985	23	—·909	34	— 842
13	—·977	24	—·903	35	—·847
14	—·970	25	—·897	36	—·832
15	—·963	26	—·892	37	—·837
16	—·955	27	—·886	38	—·822
17	—.949	28	—·880	39	—·822
18	—.942	29	—·874	40	—·817
19	—·935	30	—·867		
20	—·928	31	—·861		

Baumé's Hydrometer for Liquids heavier than Water. Temperature 55° Fahrenheit.

Degrees.	Sp. Grav.	Degrees.	Sp. Grav.	Degrees.	Sp. Grav.
0	1·000	27	1·230	51	1.547
3	1·020	30	1·261	54	1·594
6	1·040	33	1·295	57	1·659
9	1·064	36	1·333	60	1·717
12	1·089	39	1·373	63	1·779
15	1·114	42	1·414	66	1·848
18	1·140	45	1·455	69	1·920
21	1·170	48	1·500	72	2·000
24	1·200				

of the Degrees of different Thermometers (omitting ections) at which some chemical Phenomena occur.

	Fahr.	Reau.	Cent.	Wedg.
luced by Mr. Walker	— 90	— 54	— 68	
d freezes	— 66	— 44	— 55	
freezes	— 39	— 32	— 39	
ezes	— 7	— 17	— 14	
luced by mixing equal parts and muriate of soda	0	— 14	— 18	
ines freeze	20	— 5	— 6	
ezes	32	0	0	
rmentation begins	59	12	15	
id, and acetous begins	77	20	25	
rmentation ceases	88	25	31	
ils	98	29	36	
ti melts	112	36	45	
elts	127	42	53	
separates from water	130	44	54	
x melts	142	49	61	
ublimes	145	50	62	
wax melts	155	55	69	
waporates	170	61	77	
oils	176	64	80	
ils	212	80	100	
elts	234	89	111	
cid boils	242	93	116	
urns slowly	303	120	150	
s	442	182	227	
acid boils	590	248	310	

Table of Freezing Mixtures.—From Mr. Walker's Papers in the Philosophical Transactions.

A Mixture of		Reduces the Temperature
Sulphate of soda	8	from 50° to 0°
Muriatic acid	5	
Snow	1	from 32° to 0°
Muriate of soda	1	
Snow	2	from 0° to —5°
Muriate of soda	1	
Snow	1	from —5° to —18°
Muriate of soda	5	
Muriate of ammonia and nitrate of potass, of each	5	
Snow	1	from 20° to —60°
Diluted sulphuric acid	1	
Snow	1	from —40° to —73°
Muriate of lime	3	
Snow	8	from —68° to —91°
Diluted sulphuric acid	10	

The salts ought to be fresh crystallized, and reduced to very fine powder, and the mixtures made in thin vessels as quickly as possible.

Numerical Expression of Chemical Affinities.—By M. Morveau.

	Sulphuric Acid.	Nitrous Acid.	Muriatic Acid.	Acetous Acid.	Carbonic Acid.
Barytes	65	62	36	29	14
Potash	62	58	32	26	9
Soda	58	50	28	25	8
Lime	54	44	20	19	12
Ammonia	46	38	14	10	4
Magnesia	50	40	16	17	6
Argil	40	36	10	15	2

Note. The above table, showing the comparative force of attraction between the aforesaid bodies, may be useful to point out the probability of any particular decomposition, previous to the attempt being made.

ir Crystals.	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water.	
			60°	Boiling.
and plates	Little	Decrepitates	9	30
	None	Melts	14	200
cubes	Softens	Decrepitates	33	100
	None	Ditto	20	
isms	Deliquesces	Fuses and decomposes	400	Still more
	Ditto	Watery fusion	50	200
s and four- ns	Ditto	Fusible	100	
vstallize	Ditto	Decomposes	Extremely soluble	
l octagons	Unalterable	Decrepitates	18	
	Moistens a little	Ditto	33	
	Ditto and dries again	Ditto	35	36
	Unalterable	Melts	120	
ditto	Very deliquescent	Ditto	200	
	None	Fusible and volatile	30	100
or jelly	Deliquesces	Ditto and decomposes	100	
plates	None	Ditto and ditto	5	33
ler	Ditto	Fusible in great heat	Insoluble	Insoluble
	Ditto	Ditto	Ditto	Ditto
ms	Ditto	Ditto with difficulty	Ditto	Ditto
ky threads	Moistens a little	Softens and dries		
	Effloresces outwardly	Aqueous fusion	25	30

A TABLE *of the* PROPERTIES *of several of the* SALTS, *arranged in each Class according to the Affinities of their Radicals for the Acids.*

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat.*	*Solubility in 100 Parts of Water.*	
						60°	*Boiling.*
Sulphate of barytes	Native	None		None	Decrepitates	Insoluble	Insoluble
——— potass	Artificial	Bitter and acrid	Six-sided prisms	Ditto	Ditto	6	20
——— ditto super	Ditto	Sharp and not	Ditto	Little	Fusible	50	100
——— soda	In sea water	Bitter and cool	Ditto grooved	Efloresces	Aqueous fusion	20	45
——— strontian	Native	None	Needles intersecting each other	None	Fusible at a high temperature	Insoluble	Insoluble
——— lime	Ditto	Hardly perceptible	Quadrangular prisms	Ditto	Calcines and melts	Nearly inso.	Nearly insol.
——— ammonia	Artificial		Six-sided prisms	Little	Aqueous fusion	50	50 little more
——— magnesia	In sea water	Bitter and cool	Four-sided ditto, ending in pyramids	Slightly efflorescent	Ditto	100	133
——— ditto and ammonia	Artificial	Ditto and acrid	Octahedrons	None	Ditto	Little soluble	Little soluble
——— alumine super	Ditto	Astringent	Thin pearly crystals	Little	Dries to powder	Moderately	Moderately
——— ditto and potass	Ditto	Ditto and styptic	Octahedrons	Ditto	Melts and dries	5	75
Sulphite of barytes	Ditto	Little	Tetrahedrons	Ditto		Insoluble	Insoluble
——— lime	Ditto	Sulphureous	Six-sided prisms	Efflores-ces	Dries to powder	½ of a part	
——— potass	Ditto	Ditto sharp and acrid	Various	Ditto	Decrepitates	100	Still more
——— soda	Ditto	Ditto and cool	Four-sided prisms	Ditto	Watery fusion	25	100
——— ammonia	Ditto	Cool	Six-sided ditto, and various	Deliquesces	Decrepitates	100	
——— magnesia	Ditto	Sweet and earthy	Flat transparent tetrahedrons	Efflorescs	Softens and dries	5	
——— alumine	Ditto	Sulphureous and earthy	In white powder	Changes to sulphate	Decomposes	Insoluble	Insoluble

(Table continued.)

Salts.	*Origin.*	*Taste.*	*Form of their Crystals.*	*Action of the Air.*	*Action of Heat*	*Solubility in 100 Parts of Water.*	
						60°	*Boiling.*
Nitrate of barytes	Artificial	Hot, acrid, and rough	Octahedrons and plates	Little	Decrepitates	9	30
——— potass	Native	Cool and bitter	Various	None	Melts	14	200
——— soda	Artificial	Ditto	Rhomboidal cubes	Softens	Decrepitates	33	100
——— strontian	Ditto	Cool and penetrating	Octahedrons	None	Ditto	20	
——— lime	Ditto and native	Acrid, hot, and bitter	Six-sided prisms	Deliquesces	Fuses and decomposes	400	Still more
——— ammonia	Artificial	Acrid and bitter	Various	Ditto	Watery fusion	50	200
——— magnesia	From mother waters of nitre	Bitter	Small needles and four-sided prisms	Ditto	Fusible	100	
——— alumine	Artificial	Astringent	Does not crystallize	Ditto	Decomposes	Extremely soluble	
Muriate of barytes	Ditto	Pungent	In tables and octagons	Unalterable	Decrepitates	18	
——— potass	Ditto	Pure saline taste	Cubes	Moistens a little	Ditto	33	
——— soda	Sea and rocks	Ditto	Ditto	Ditto and dries again	Ditto	35	36
——— strontian	Artificial	Pungent	Fine prisms	Unalterable	Melts	120	
——— lime	Mineral waters	Ditto	Needle-like ditto	Very deliquescent	Ditto	200	
——— ammonia	Native	Bitter	Various	None	Fusible and volatile	30	100
——— magnesia	In waters	Ditto and disagreeable	In powder, or jelly	Deliquesces	Ditto and decomposes	100	
Oxygenized muriate of potass	Artificial	Cool and harsh	Square thin plates	None	Ditto and ditto	5	33
Phosphate of barytes	Ditto	Insipid	Heavy powder	Ditto	Fusible in great heat	Insoluble	Insoluble
——— strontian	Ditto	Ditto	White ditto	Ditto	Ditto	Ditto	Ditto
——— lime	Native	Ditto	Various prisms	Ditto	Ditto with difficulty	Ditto	Ditto
——— ditto super	Artificial	Sour	Plates or silky threads	Moistens a little	Softens and dries		
——— soda	Ditto	Mild, saline	Various	Effloresces outwardly	Aqueous fusion	25	50

(Table continued.)

Salts.	Origin.	Taste.	Form of their Crystals	Action of the Air.	Action of Heat.	Solubility in 100 Parts of Water.	
						60°	Boiling.
Phosphate of ammonia	Artificial	Salt and urinous	Four-sided prisms, ending in pyramids	None	Aqueous fusion	25	50 rather more
——— ditto and soda	In urine			Effloresces			
Phosphite of lime	Artificial	Acid	Small needles	None	Decomposes	Sparingly	
——— barytes	Ditto	Insipid	White powder	Ditto	Melts	Ditto	
——— magnesia	Ditto	Ditto	Flaky crystals	Effloresces	Ditto	$\frac{1}{4}$th of a part	
——— potass	Ditto	Sharp	Four-sided prisms	Little	Decrepitates and melts	33	
——— soda	Ditto	Mild and cool	Irregular ditto	Effloresces	Melts	50	50
——— ammonia	Ditto	Sharp	Needles and prisms	Deliquesces	Ditto and decomposes	50	
Fluate of lime	Native	None	Various	None	Decrepitates	Insoluble	
——— soda	Artificial	Bitter	Cubes	Ditto	Ditto	Difficult	
Borate of lime	Ditto and Native	Insipid	White powder			Ditto	
——— ditto and magnesia	Native	Ditto	Polyhedron with 22 faces	None	Decrepitates	Insoluble	
——— soda	Ditto	Alkaline and sweet	Irregular	Effloresces	Aqueous fusion	$8\frac{1}{2}$	17
——— of barytes	Ditto		Striated masses	None	Fuses	Nearly insol.	
——— potian	Ditto	None	Striated prisms	Ditto	Ditto and decomposes	Ditto	
——— soda	Native	None	Various	Ditto	Decrepitates	Insoluble	
——— magnesia	Artificial	Urinous	Square prisms terminated by square pyramids	Crystals effloresce	Aqueous fusion	25	80
——— ammonia	Ditto		Irregular octahedrons	Ditto much	Ditto	50	100
		Little	Small prisms	Ditto	Decrepitates	2	if crystallized
			Irregular	Unalterable	Sublimes	50	100

EXPERIMENTS.

NOTHING tends to imprint chemical facts upon the mind so much as the exhibition of interesting Experiments. With this view the following Selection has been made, in which such experiments as may be performed with ease and *safety*, have uniformly been preferred.

No. 1. Take a small phial about half full of cold water; grasp it gently in the left hand, and from another phial pour a little sulphuric acid very gradually into the water. A strong SENSATION OF HEAT will immediately be perceived. This, by the continued addition of the acid, may be increased to many degrees beyond that of boiling water. See pages 73 and 84.

2. Take a small phial, in one hand, containing some pulverized muriate of ammonia; pour a little water upon it, and shake the mixture. In this instance a SENSATION OF COLD will immediately be felt. See page 76.

3. Into a tea-cup, placed upon a hearth, and containing about a table spoonful of oil of turpentine, pour about half the quantity of strong nitrous acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, FLAME will be produced. *In performing this experiment it is advisable to mix the acids in a phial, to tie the phial to the end of a stick*, and at arm's length,

to pour its contents into the oil; as the sudden combustion sometimes occasions a part of the liquids to be thrown out of the vessel. See note, page 74.

4. Put about an ounce of marble grossly pulverized into an eight-ounce phial, with about an equal quantity of water. Pour upon it a little sulphuric acid, and CARBONIC ACID GAS will be evolved.* See page 284.

5. Put about an ounce of iron filings into a phial with about three or four ounces of water; pour a little sulphuric acid upon the contents, and HYDROGEN GAS will be evolved. See notes, page 104.

6. Pour water into a small glass retort so as to occupy about one third of its capacity, lute its beak into the end of a gun barrel, the middle of which must be kept red-hot in a furnace, or by a chaffing-dish; then if a lamp be applied to the retort so as to cause the water to boil, the steam will pass through the red-hot iron tube, and in this case also will be decomposed; for, as the oxygen combines with the iron, the HYDROGEN GAS will be liberated, and may be collected in the usual way. See page 101.

7. Put some sulphuret of iron into a phial, pour a little diluted sulphuric acid over it, and attach a bladder, prepared as directed for experiment No. 4, to the phial. SULPHURETTED HYDROGEN, a gas extremely fetid and disagreeable, will immediately be evolved; though the ingredients here employed were destitute of smell. See page 253.

8. Put an ounce or two of the black oxide of manganese into a small glass retort, pour a little concentrated sulphuric acid upon it, and apply the heat of a lamp. OXYGEN GAS will be disengaged in abundance. See Additional Notes, No. 7.

9. Into a small glass retort put a mixture of two parts of quicklime, and one of muriate of ammonia, both in powder. Apply the heat of a lamp, and AMMONIACAL GAS will come over. See page 164.

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* The cheapest receiver for the collection of this and other gases is a moistened bladder, with a piece of tobacco pipe firmly tied into its neck, and twisted in such a manner as to expel all the common air. This may easily be adapted to any vessel by means of the pipe, which may be fixed in the cork, and closely luted in the usual way.

10. Pour a little sulphuric acid upon a small quantity of quicksilver in a glass retort, apply heat, and SULPHUROUS ACID GAS may be collected. See page 178.

11. Take a few shreds or filings of copper, and pour over them a little diluted nitrous acid, in the proportion of about three parts of water to one of acid. The gas evolved in this case is NITROUS GAS. See page 185.

12. Upon an ounce or two of nitrate of potass in a glass retort pour some sulphuric acid; give it heat by means of a lamp, and collect NITROUS ACID. See page 184.

13. Treat muriate of soda in the same manner with sulphuric acid, and MURIATIC ACID in the gaseous form will rise from the retort. See note, page 180.

14. Convey some muriatic acid gas into a glass jar containing a portion of the gas produced in experiment 9. From the mixture of these two invisible gases a SOLID SUBSTANCE will be produced, viz. the common sal-ammoniac; this may be perceived to deposit itself upon the sides of the vessel in a neat crystallized form. See pages 165 and 166.

15. Convey some carbonic acid gas into a glass jar containing a portion of ammoniacal gas. The instant the two gases come into contact a great absorption will take place, and SOLID CARBONATE OF AMMONIA will be formed on the inner surface of the jar. See page 164.

16. If common Glauber's salt be dried and reduced to powder, as directed note †, page 237, and then dissolved in three times its weight of boiling water, it will not only be found to crystallize again on cooling, but the crystals will assume the identical forms which they exhibited before they were pulverized. This experiment is designed to show that a DETERMINATE FIGURE has been instamped upon every INDIVIDUAL SALT.

17. Dissolve $\frac{1}{4}$ of an ounce of Glauber's salt in two ounces of boiling water, pour it while hot into a phial and cork it close. In this state it will not crystallize, even when perfectly cold; but if the cork be now removed, the crystallization will be seen to commence and proceed with rapidity; affording an instance of the effect of ATMOSPHERIC AIR on CRYSTALLIZATION. See page 234.

18. Repeat the experiment with a small thermometer immersed in the solution, and closed so as to exclude the atmospheric air. If the solution be suffered to cool completely under

these circumstances, the thermometer will be seen to rise on the removal of the cork. This experiment is designed to show that saline solutions give out CALORIC in the act of CRYSTALLIZATION. See note, page 76.

19. Put about half an ounce of quicksilver into a wine-glass, and pour about an ounce of diluted nitrous acid upon it. The nitrous acid will be decomposed by the metal with astonishing rapidity; the bulk of the acid will be quickly changed to a beautiful green, while its surface exhibits a dark crimson: and an effervescence indescribably vivid and pleasing will go on during the whole time the acid operates upon the quicksilver. When a part only of the metal is dissolved, a change of colour will again take place, and the acid by degrees will become paler, till it is as pellucid as pure water. This is one instance of a METALLIC SOLUTION by means of an ACID; in which the opacity of a metallic body is completely overcome, and the whole rendered perfectly transparent.

20. Take the metallic solution formed in the last experiment, add a little more quicksilver to saturate the acid; then place it at some distance over the flame of a lamp, so as gently to evaporate a part of the water. The new formed salt will soon be seen to begin to shoot into needle-like prismatic crystals, crossing each other in every possible direction; affording an instance of the FORMATION of a METALLIC SALT.

21. Pour a drachm by weight of strong nitrous acid into a wine-glass, add two drachms of distilled *water*,* and, when mixed, throw a few very small pieces of granulated tin into it. A violent effervescence will take place, the lighter particles of the tin will be thrown to the top of the acid, and be seen to play up and down in the liquor for a considerable time, till the whole is dissolved. This is another example of a TRANSPARENT LIQUID holding a METAL IN SOLUTION.

22. Dissolve one ounce of quicksilver *without* heat in $\frac{1}{2}$ of an ounce of strong nitrous acid, previously diluted with one ounce and a half of water. Dissolve also the same weight of quicksilver, *by means of heat*, in the same quantity of a similar acid, and then to each of these colourless solutions add a colourless solution of ammonia. In the one case, the metal will be precipitated in a *black*, in the other, in a *white* powder, affording an ex-

* Where distilled water is not at hand, clean rain water will answer nearly as well for most purposes.

ample of the difference of colour of metallic oxides, arising from DIFFERENT DEGREES OF OXIDIZEMENT. See page 356.

23. Take an ounce of a solution of potass, pour upon it half an ounce of sulphuric acid; lay the mixture aside, and when cold, crystals of sulphate of potass will be formed in the liquor. Here a MILD SALT has been FORMED from a mixture of two *corrosive* substances. See page 147.

24. Take carbonate of ammonia (the common volatile *smelling* salt,) and pour upon it muriatic acid so long as any effervesence continues. The produce will be a SOLID SALT perfectly *inodorous*, and of little taste. See page 165.

25. Take caustic soda one ounce, pour over it one ounce of muriatic acid, both of these corrosive substances. The produce will be our COMMON TABLE SALT. See page 147.

26. Mix in a wine-glass equal quantities of a saturated solution of muriate of lime, and a saturated solution of carbonate of potass, both transparent *fluids:* stir the mixture, and a SOLID MASS will be the product. See page 240.

27. Take the substance produced in the foregoing experiment, and pour a very little nitric acid upon it. The consequence will be, the solid matter will again be taken up, and the whole exhibit the appearance of one homogeneous fluid. An instance of a solid *opaque* mass being converted by a chemical agent to a TRANSPARENT LIQUID. See pages 133 and 241.

28. Take a transparent saturated solution of sulphate of magnesia, (Epsom salt,) and pour into it a like solution of caustic potass or soda. The mixture will immediately become almost SOLID. This instance of the sudden conversion of two fluids to a solid, and that related No. 26, have been called *chemical miracles*. See page 241.

29. Take a portion of dried sulphate of iron, and an equal quantity of nitrate of potass, grind them together in a mortar, and put the whole into a small glass retort. Adapt a receiver to the retort with one or two bottles, according to the plan of Woulfe's apparatus, and apply the heat of an Argand lamp. After some time a gas will be disengaged, which will be condensed by the colder receiver forming the true *nitrous acid.* We have here a CORROSIVE FLUID produced from the mixture of two *mild* and *solid* substances. See page 185.

30. Pour a little pure water into a small glass tumbler and

put one or two small pieces of phosphuret of lime into it. In a short time FLASHES OF FIRE will dart from the surface of the water, and terminate in ringlets of smoke, which will ascend in regular succession. See page 261.

31. Put thirty grains of phosphorus into a Florence flask with three or four ounces of water. Place the vessel over a lamp, and give it a boiling heat. Balls of fire will soon be seen to issue from the water, after the manner of an artificial fire-work, attended with the most beautiful coruscations. An experiment to show the extreme INFLAMMABILITY OF PHOSPHORUS. See note* page 262.

32. Into an eight-ounce retort pour four ounces of pure water, add a little solution of pure potass, and give it a boiling heat with a lamp. When it boils, drop a small piece of phosphorus into it, and immerse the beak of the retort in a vessel of water. Bubbles of PHOSPHURETTED HYDROGEN GAS will issue from the retort, rise through the water, and take fire the moment they come in contact with atmospheric air, somewhat similar to the appearance mentioned at experiment No. 30. See page 256.

33. Fix a small piece of solid phosphorus in a quill, and write with it upon paper. If the paper be now carried into a dark room, the writing will be BEAUTIFULLY LUMINOUS. See page 262.

34. Pour a little phosphuretted ether upon a lump of sugar, and drop it into a glass of water, a little warm. The surface of the water will soon become luminous; and if it be moved by blowing gently with the mouth, beautiful and brilliant undulations of its surface will be produced, exhibiting the appearance of a LIQUID COMBUSTION. See page 262.

35. If any part of the body be rubbed with liquid phosphorus, or phosphuretted ether, that part, in a dark room, will appear as though it were ON FIRE, without producing any dangerous effect, or sensation of heat. See page 262.

36. Take about six grains of oxymuriate of potass, and three grains of flour sulphur; rub them together in a mortar, and a smart DETONATING NOISE will be produced. Continue to rub the mixture hard, and the reports will be frequently repeated, accompanied with vivid flashes of light. If the same mixture be wrapped in paper, laid on an anvil, and smartly struck with a hammer, the report will be as loud as what is usually produced by a pistol. See page 221.

37. Take ten grains of the oxymuriate of potass, and

one grain of phosphorus. Treat this mixture as in the last experiment, and very VIOLENT DETONATIONS will be produced. It is advisable *never to exceed* the quantity of phosphorus that is prescribed here, and in other similar experiments.

38. Take a similar quantity of oxymuriate of potass with three or four grains of flour sulphur, and mix the ingredients very well on paper. If a little of this mixture be taken up on the point of a knife and dropped into a wine-glass containing some sulphuric acid, a beautiful COLUMN OF FLAME will be perceived, the moment the powder comes in contact with the acid.

39. Put a little oxymuriate of potass and a bit of phosphorus into an ale-glass, pour some cold water upon them cautiously, so as not to displace the salt. Now take a small glass tube, and plunge it into some sulphuric acid: then place the thumb upon the upper orifice, and in this state withdraw the tube, which must be instantly immersed in the glass, so that, on removing the thumb, the acid may be immediately conveyed upon the ingredients. This experiment is an example of a very singular phenomenon, COMBUSTION UNDER WATER.

40. Proceed in all respects as in the last experiment, and add a morsel of phosphuret of lime. Here, besides the former appearance, we shall have COMBUSTION also ON THE SURFACE OF THE WATER.

41. Prepare a mixture of equal parts of lump sugar and oxymuriate of potass; put a small quantity of this mixture upon a plate or a tile; then dip a piece of sewing-thread into a phial of sulphuric acid, so as to convey the smallest quantity of the acid with this touch the powder, and an immediate BURST OF FLAME will be the consequence.

42. Mix, without much friction, ten grains of oxymuriate of potass with one grain of phosphorus, and drop the mixture into concentrated sulphuric acid. This is an instance of DETONATION AND FLAME being produced, by the mixture of a powder with a *cold* liquid. See page 221.

43. Pour boiling water upon a little red cabbage sliced, and when cold decant the clear infusion. Divide the infusion into three wine glasses. To one add a solution of alum, to the second a little solution of potass, and to the third a few drops of muriatic acid. The liquor in the first glass will assume a purple, the second a bright green, and the third a beautiful

crimson. Here is an instance of THREE DIFFERENT COLOURS from the same vegetable infusion, merely by the addition of three *colourless* fluids. See pages 147 and 170.

44. Prepare a little tincture of litmus. Its colour will be a bright blue with a tinge of purple. Put a little of it in a phial, and add a few drops of diluted muriatic acid; its colour will change to a *vivid red*. Add a little solution of potass; the red will now disappear, and the *blue* will be restored. By these means the liquor may be changed alternately from a red to a blue, and from a blue to a red, at pleasure. An instance of the effects of acids and alkalies in CHANGING VEGETABLE COLOURS. See page 147.

45. Make an infusion of red roses, violets, or mallow flowers; treat it with solution of potass, and it will become *green*; the addition of diluted muriatic acid will convert it immediately to a *red*. This experiment may be as frequently varied as the last, and furnishes an excellent TEST FOR ACIDS AND ALKALIES.

46. Add a drop or two of solution of potass to tincture of turmeric. This will change its original bright *yellow* colour to a dark *brown*: a little colourless diluted acid will restore it. By this tincture we can detect the most minute portion of any ALKALI IN SOLUTION.

47. Into a wine-glass of water put a few drops of prussiate of potass; and a little dilute solution of sulphate of iron into another glass: by pouring these two *colourless* fluids together, a BRIGHT DEEP BLUE COLOUR will be immediately produced, which is the true prussian blue.

48. Put some prussiate of potass into one glass; into another a little nitrate of bismuth. On mixing these COLOURLESS fluids, a YELLOW will be the product.

49. Pour a little prussiate of potass into a glass containing a *colourless* solution of sulphate of copper, and a REDDISH BROWN will be produced, being a true prussiate of copper. See page 314.

50. Prepare a phial with pure water and a little tincture of galls; and another with a weak solution of sulphate of iron: then mix these transparent COLOURLESS fluids together, and they will instantly become BLACK. See page 200.

51. Pour a little tincture of litmus into a wine-glass, and into another some diluted sulphate of indigo; pour these two BLUE fluids together, and the mixture will become perfectly RED. See page 147.

52. Drop as much nitrate of copper into water as will form a colourless solution: then add a little ammonia, equally COLOURLESS, and an intense BLUE COLOUR will arise from the mixture.

53. Take water holding carbonate of iron in solution, and add some diluted prussiate of potass: PRUSSIAN BLUE will be formed by the mixture. See page 204.

54. Take some of the same water as that used in the last experiment: boil it, and now add prussiate of potass. In this case NO COLOUR will be produced.

55. Take some water impregnated with carbonic acid, and add to it a little BLUE tincture of litmus. The whole will be changed to a RED. See page 147.

56. Take some of the same carbonated water, and boil it. Then add a little tincture of litmus, and the blue colour will experience NO CHANGE.

57. Take some of the black liquid described in experiment 50, add by degrees muriatic acid to it, and the COLOUR WILL BE DISCHARGED. Now drop in a little solution of potass, and the black colour will be RESTORED. Some nicety is requisite in adding the acid and alkali; for if they be given in excess the effects will not be so apparent.

58. Take the blue solution formed by the experiment No. 52, add a little sulphuric acid, and the colour will *disappear;* pour in a little solution of caustic ammonia, and the BLUE COLOUR WILL BE RESTORED. Thus may the liquor be alternately changed at pleasure. See pages 147 and 170.

59. Spread a piece of tinfoil, such as is used for coating electrical jars, upon a piece of thick paper; pour a small quantity of strong solution of nitrate of copper upon it. Fold it up quickly, and wrap it round carefully with the paper, more effectually to exclude the atmospheric air. Place it then upon a file, and in a short time *combustion* will commence, and the TIN WILL INFLAME.

60. Take three parts of nitre, two of potass, and one of sulphur; all of these should be thoroughly dry; then mix them by rubbing them together in a warm mortar; the resulting compound is called *fulminating powder*. If a little of this powder be placed upon a fire-shovel over a hot fire, it gradually blackens, and at last melts. At that instant it EXPLODES WITH A VIOLENT REPORT. *Note, this mixture is not dangerous, like the metallic fulminating powders; none of which should be intrusted in the hands of young people.*

61. Whenever uncombined muriatic, or any volatile acid is suspected to be present in any chemical mixture, it may be detected by ammonia. A single drop of ammonia on a feather, or small slip of paper, held over the mixture, will immediately render the VAPOUR VISIBLE.

62. Ammonia in solution may in like manner be detected by a single drop of muriatic, or acetic acid, which will produce very evident WHITE FUMES. This is merely the reverse of the former experiment. See note, page 166.

63. Procure a bladder furnished with a stop cock, *fill* it with hydrogen gas, and then adapt a tobacco-pipe to it. By dipping the bowl of the pipe into a lather of soap, and pressing the bladder, soap-bubbles will be formed, filled with hydrogen gas. These bubbles will rise into the atmosphere, as they are formed, and convey a good idea of the principle upon which AIR-BALLOONS are inflated. See page 33.

64. Procure a bladder similar to that described in the last experiment, and charge it with a mixture of oxygen and hydrogen gases. With this apparatus blow up soap bubbles as before, and touch them with a lighted match. The bubbles as they rise will EXPLODE WITH A SMART NOISE. See note, 251.

65. Fill a [illegible] as that directed in Experiment No. 3, with hydrogen gas; apply a lighted match to the end of the tobacco pipe, and press the bladder gently. A PENCIL OF FLAME, extremely beautiful, will be seen issuing from the pipe. Fill the whole of the hydrogen [illegible] See note 5, page 190.

66. Place [illegible] phials on the [illegible] pneumatic [illegible] filled with water, and inverted as usual for receiving gases. Now fill them with mixed *oxygen and hydrogen* [illegible] from the bladder, as described in Experiment 64. A lighted match will cause any one of them to EXPLODE WITH VIOLENCE. When the phials are used, it will be prudent to cover them round with a handkerchief, to prevent any injury being received from the glass in case of bursting; but if small bladders be employed in place of the phials, this precaution will be unnecessary. See note 7, 251.

67. Pour a little lime water into a wine glass, and put some solution of oxalate of ammonia, equally transparent, into another glass. If the two clear liquors be poured together, a white precipitate of OXALATE OF LIME will immediately become visible. See note 5, 197.

68. Pour a little lime-water into a phial, and throw some carbonic acid into it. The carbonic acid will seize the lime, and precipitate it in the state of CARBONATE OF LIME.

69. Take the phial made use of in the last experiment, with its contents, and convey an additional portion of carbonic acid into it. The carbonate of lime will now be RE-DISSOLVED, and the liquor rendered TRANSPARENT. See note †, page 134.

70. Take the transparent liquid produced in the last experiment, and give it heat. The earth will now be precipitated in the state of CARBONATE OF LIME, as before.

71. Pour some lime-water into a wine-glass, and a little solution of carbonate of potass into another glass. When these two transparent fluids are thrown together, an abundant precipitate of CARBONATE OF LIME will be the consequence. See page 159

72. Proceed as in the last experiment, but instead of carbonate of potass, pour a solution of Epsom salt into one of the glasses. When these transparent fluids are poured together, a mixed precipitate of CARBONATE OF MAGNESIA, and SULPHATE OF LIME, will be produced. See page 140.

73. For another experiment, take in the same manner, separately, lime-water and a solution of alum. The union of these solutions will produce a mixed precipitate of ALUMINE and SULPHATE OF LIME.

74. If a strong solution of caustic potass and a saturated solution of Epsom salt be mixed, the union of these transparent fluids will produce also an abundant precipitate. But this will consist of MAGNESIA and SULPHATE OF POTASS.

75. To a glass of water, suspected to contain carbonic acid, add a small quantity of any of the other acids. If carbonic acid be present, it will become visible by a SPARKLING APPEARANCE on the sides of the glass and surface of the fluid.

76. Prepare two glasses of pure water, and into one of them drop a single drop of sulphuric acid, and mix it with the water. Pour a little muriate of barytes into the other glass, and no change will be perceived; pour some of the same solution into the first glass, containing the sulphuric acid, and a white precipitate of SULPHATE OF BARYTES will be produced. See note, page 131.

77. Prepare two glasses of water as before, conduct the experiment in the same way as the last, but instead of muriate of

barytes, use *nitrate of lead*. In this case SULPHATE OF LEAD will be precipitated. See page 330.

78. Prepare two glasses of rain water, and into one of them drop a single drop of sulphuric acid. Pour a little *nitrate of silver* into the other glass, and no change will be perceptible. Pour some of the same solution into the first glass, and a white precipitate of SULPHATE OF SILVER will appear.

79. Prepare two glasses as in the last experiment, and into one of them put a drop or two of *muriatic acid*. Proceed as before, and a precipitate of MURIATE OF SILVER will be produced. See last note of page 299.

80. Take two glasses, as in experiment 78, and into one of them put a drop of sulphuric acid, and a drop or two of muriatic acid: proceed as before with the *nitrate of silver*, and a MIXED precipitate will be produced, consisting of MURIATE OF SILVER and SULPHATE OF SILVER.

81. Take the glass containing the mixed precipitate of the last experiment, and give it, by means of a lamp, the heat of boiling water. The sulphate of silver, if there be a sufficiency of water, will now be re-dissolved, and the muriate of silver will remain separate at the bottom of the vessel. This experiment exhibits a method of SEPARATING these METALLIC SALTS whenever they occur in a state of mixture.

82. Mix one ounce of litharge of lead with one drachm of pulverized muriate of ammonia, and submit the mixture to a red heat in a clean tobacco-pipe. The increase of temperature will separate the ammonia in the form of gas, and the muriatic acid will combine with the lead. When the compound is well melted, pour it into a metallic cup and you will have a true MURIATE OF LEAD of a bright yellow colour, the brilliancy of which may be much heightened by grinding it as usual with oil. In this state it forms the colour called PATENT YELLOW. See note †, page 236.

83. Take one ounce of red-lead, and half a drachm of charcoal in powder, incorporate them well in a mortar, and then fill the bowl of a tobacco-pipe with the mixture. Submit it to an intense heat in a common fire, and when melted, pour it upon a slab. The result will be METALLIC LEAD completely revived. See page 442.

84. Take a little *red-lead*, expose it to an intense heat in a crucible, and pour it out when melted. The result will be metallic glass, and will furnish an example of the VITRIFICATION OF METALS.

85. Pour a little solution of indigo in sulphuric acid into a glass of water, and add about an equal quantity of solution of *carbonate of potass*. If a piece of white cloth be dipped in this mixture, it will come out a BLUE. If a piece of yellow cloth be dipped in, it will become a GREEN, or a red will be converted to a PURPLE. A slip of blue litmus paper immersed in it will immediately become RED.

86. If a little fustic, quercitron bark, or other dye, be boiled in water, the colouring matter will be extracted, and a coloured solution formed. On adding a small quantity of dissolved alum to this decoction, the alumine, or base of the salt, will attract the colouring matter, forming an INSOLUBLE COMPOUND, which in a short time will subside, and may easily be separated. See Additional Notes, No. 11.

87. Boil a little cochineal in water, with a grain or two of cream of tartar, (supertartrate of potass,) and a dull kind of crimson solution will be formed. By the addition of a few drops of nitro-muriate of tin, the colouring matter will be PRECIPITATED OF A BEAUTIFUL SCARLET. This, and some of the former instances, will give the student a tolerably correct idea of the general process of dyeing woollen cloths. See note, page 327.

88. If a few strips of dyed linen cloth, of different colours, be dipped into a phial of oxymuriatic acid, the colours will be quickly discharged; for there are few colours that can resist the energetic effect of this acid. This experiment may be considered as a complete example of the process of BLEACHING coloured goods. See first note, page 184.

89. Having found a piece of blue linen cloth, that will bleach in oxygenized muriatic acid, dip the tip of the finger in a solution of *muriate of tin*, and press it while wet with the solution, upon a strip of this cloth. After an interval of a few minutes immerse the cloth in a phial of liquid oxymuriatic acid, and when it has remained in it the usual time, it will be found that the spot which was previously wet with muriate of tin has preserved its ORIGINAL COLOUR, while the rest of the cloth has become WHITE. See last note, page 325.

90. Dip a piece of white calico in a strong solution of acetate of iron; dry it by the fire, and lay it aside for three or four days. After this, wash it well in hot water, and then dye it black by boiling it for ten minutes in a strong decoction of Brazil wood. If the cloth be now dried, any figures printed upon it with a *colourless* solution of muriate of tin, will appear

BEAUTIFUL SCARLET, although the ground will re- permanent BLACK. See note *, page 327.

Dissolve 4 drachms of sulphate of iron in one pint of cold then add about 6 drachms of lime in powder, and 2 ns of finely pulverized indigo, stirring the mixture occa- y for 12 or 14 hours. If a piece of white calico be im- l in this solution for a few minutes, it will be dyed N; and by exposure to the atmosphere only for a few s, this will be converted to a PERMANENT BLUE. dditional Notes, No. 52.

If a piece of calico be immersed in a solution of sulphate , and when dry washed in a weak solution of carbonate ass, a PERMANENT COLOUR will be produced, viz. UFF of the calico-printers. See note 325.

Boil equal parts of arnotto and common potass in water e whole are dissolved. This will produce the PALE DISH BUFF so much in use, and sold under the name of KEEN DYE.

If muriate of tin, newly made, be added to a solution of in sulphuric acid, the oxygen of the indigo will be ab- , and the solution instantly converted to a *green*. It is same principle that muriate of tin is employed in cleans- coloured leather furniture; as it absorbs the oxygen, and

acid by means of the block, is another method by which calico-printers give the WHITE SPOTS or FIGURES to PIECE-GOODS. The crystallized acid in a state of solution is generally used for this purpose. *These few experiments will give the student some idea of the nature of calico-printing.*

98. Take a slip of blue litmus paper, dip it into acetous acid, and it will immediately become red. This is a test so delicate, that, according to Bergman, it will detect the presence of sulphuric acid, even if the water contain only one part of acid to thirty-five thousand parts of water. Litmus paper which has been thus changed by immersion in acids, is, when dried, a good test for the alkalies; for, if it be dipped in a fluid containing the smallest portion of alkali, the red will disappear, and the paper be restored to its ORIGINAL BLUE COLOUR. See note ‡, page 170.

99. Take a slip of turmeric paper, and dip it into any alkaline solution; this will change the yellow to a deep brown. In many cases turmeric is preferable to litmus paper for detecting alkali in solution, as it suffers no change from carbonate of lime, which is often found in mineral waters. This paper will detect the presence of soda, though it should amount to no more than $\frac{1}{2200}$dth part of the water. The paper thus changed by an alkali, would, if dried, be still useful as a test for acids, as these restore its ORIGINAL YELLOW.

100. Write upon paper with a diluted solution of muriate of copper; when dry it will not be visible, but on being warmed before the fire the writing will become of a beautiful YELLOW.

101. Write with a solution of muriate of cobalt, and the writing, while dry, will not be perceptible; but if held towards the fire, it will then gradually become visible; and if the muriate of cobalt be made in the usual way, the letters will appear of an elegant GREEN colour. See page 345.

102. Write with acetate of cobalt, or with a muriate of cobalt, previously purified from the iron which it generally contains. When the writing is become dry, these letters will also be invisible. Warm the paper a little, and the writing will be restored to a beautiful BLUE. See note †, page 347.

103. Draw a landscape with Indian ink, and paint the foliage of the vegetables with muriate of cobalt, the same as that used in Experiment No. 101, and some of the flowers with acetate of cobalt, and others with muriate of copper. While this picture is cold it will appear to be merely an outline of a landscape,

or winter scene; but when gently warmed, the trees and flowers will be DISPLAYED IN THEIR NATURAL COLOURS, which they will preserve only while they continue warm. This may be often repeated. See note, page 347.

104. Write with dilute nitrate of silver, which when dry will be entirely invisible; hold the paper over a vessel containing sulphate of ammonia, and the writing will appear very distinct. The letters will shine with the METALLIC BRILLIANCY of SILVER. See page 367.

105. Write with a solution of nitrate or acetate of lead. When the writing is dry it will be invisible. Then having prepared a glass decanter with a little sulphuret of iron strewed over the bottom of it, pour a little very dilute sulphuric acid upon the sulphuret, so as not to wet the mouth of the decanter, and suspend the writing by means of a glass stopper, within the decanter. By an attention to the paper the WRITING WILL BECOME VISIBLE by degrees, as the gas rises from the bottom of the vessel. See page 328.

106. Write with a weak solution of sulphate of iron, let it dry, and it will be invisible. By dipping a feather in tincture of galls and drawing the wet feather over the letters, the writing will be RESTORED and appear BLACK. See page 200.

107. Write with a similar solution, and when dry wash the letters in the same way with prussiate of potass, and they will be restored of a BEAUTIFUL BLUE. See last note, page 318.

108. Write with a solution of sulphate of copper, wash as before with prussiate of potass, and the writing will be revived of a REDDISH BROWN colour. See note, page 314.

109. Procure a glass jar, such as is generally used for deflagrating the gases, and fill it with oxymuriatic acid gas. If nickel, arsenic, or bismuth in powder, be thrown into this gas, and the temperature of the atmosphere be not lower than 70°, the metal will inflame, and continue to burn with the most BRILLIANT COMBUSTION. See note *, page 184.

110. Into a large glass jar, inverted upon a flat brick tile, and containing near its top a branch of fresh rosemary, or any other such shrub, moistened with water, introduce a flat thick piece of heated iron, on which place some gum benzoin in gross powder. The benzoic acid, in consequence of the heat, will be separated, and ascend in white fumes, which will at length condense, and form a most beautiful appearance upon the leaves of the vegetable. This will serve as an example of SUBLIMATION.

111. Introduce a little carbonate of ammonia into a Florence flask, and place that part of the flask which contains the salt on the surface of a basin of boiling water: the heat will soon cause the carbonate of ammonia to rise undecomposed, and attach itself to the upper part of the vessel, affording another example of SIMPLE SUBLIMATION. See page 164.

112. Fill a glass tumbler half full of lime-water; then breathe into it frequently; at the same time stirring it with a piece of glass. The fluid, which before was perfectly transparent, will presently become quite white, and if suffered to remain at rest, REAL CHALK will be deposited. See note, page 134.

113. Mix a little acetate of lead with an equal portion of sulphate of zinc, both in fine powder; stir them together with a piece of glass or wood, and no chemical change will be perceptible: but if they be rubbed together in a mortar, the two solids will operate on each other; an intimate union will take place, and a FLUID WILL BE PRODUCED. If alum or Glauber salt be used instead of sulphate of zinc, the experiment will be equally successful. See page 240 and 237.

114. If the leaves of a plant, fresh gathered, be placed in the sun as directed page 66, very pure OXYGEN GAS may be collected.

115. Put a little fresh calcined magnesia in a tea-cup upon the hearth, and suddenly pour over it as much concentrated sulphuric acid as will cover the magnesia. In an instant sparks will be thrown out, and the mixture will be COMPLETELY IGNITED.

116. If the student be in possession of an air-pump, the following experiment may be easily performed:—Let him fix a small tin cup of *ether* within a large watch-glass containing a little water, and place both under the receiver of the air-pump. The exhaustion of the receiver will cause one of the fluids to BOIL, and the other to FREEZE AT THE SAME INSTANT. See note, page 50.

117. If a few pounds of a mixture of iron filings and sulphur be made in paste with water, and buried in the ground for a few hours, the water will be decomposed with so much rapidity, that COMBUSTION AND FLAME will be the consequence.

118. Put a little alcohol in a tea-cup, set it on fire, and invert a large glass bell over it. In a short time an aqueous vapour will be seen to condense upon the inside of the bell.

which, by means of a dry sponge, may be collected, and its quantity ascertained. This may be adduced as an example of the formation of WATER BY COMBUSTION. See page 389.

119. Pour a little water into a phial containing about an ounce of olive oil. Shake the phial, and if the contents be observed we shall find that no union has taken place. But if some solution of caustic potass be added, and the phial be then shaken, an intimate combination of the materials will be formed by the disposing affinity of the alkali, and a PERFECT SOAP PRODUCED. See page 156.

120. Put a little common sulphur into an iron dish, place it under a jar of oxygen gas, and set fire to it as directed page 172, and sulphuric acid will be formed. This is an example of the formation of an ACID BY COMBUSTION.

121. Take the acid formed in the last experiment, concentrate it by boiling, mix it with a little powdered charcoal, and submit the mixture in a Florence flask to the heat of an Argand's lamp. By this process sulphur will be regenerated, and will sublime into the neck of the flask. An example of the DECOMPOSITION OF AN ACID. See page 172.

122. Drop upon a clean plate of copper, a small quantity of solution of nitrate of silver; in a short time a metallic vegetation will be perceptible, branching out in very elegant and pleasing forms, furnishing an example of METALLIC REVIVIFICATION. See page 366.

123. Dissolve an ounce of acetate of lead in about a quart or more of water, and filter the solution. If this be put into a glass decanter, and a piece of zinc suspended in it by means of a brass wire, a decomposition of the salt will immediately commence, the lead will be set at liberty, and will attach itself to the remaining zinc, forming a METALLIC TREE. See page 361.

124. Place a phial of water, enclosing a thermometer, in a frigorific mixture, and by avoiding agitation cool it some degrees below the freezing point. If it be now agitated, it immediately becomes solid, and its temperature instantly rises to 32°, an instance of a change of form occasioning an EXTRICATION of CALORIC. See page 73.

125. Fill a small glass matrass, or flask, holding about half a pint, with any kind of colouring water, having previously put in a few tea-spoonfuls of *ether*: then invert the flask in a shallow vessel of water, and by degrees pour boiling water upon

its bulb. By the sudden accession of heat the ether will be changed into vapour, which will force out the coloured water and fill the whole of the vessel. This experiment will afford an example of a liquid being converted into an ELASTIC VAPOUR BY CALORIC. See note ‡, page 86.

126. For want of a proper glass vessel, a table spoonful of ether may be put into a moistened bladder, and the neck of the bladder closely tied. If hot water be then poured upon it, the ETHER WILL EXPAND, and the bladder become inflated. See note, page 87.

127. Put a small piece of phosphorus into a crucible, cover it closely with common chalk, so as to fill the crucible. Let another crucible be inverted upon it, and both subjected to the fire. When the whole has become perfectly red-hot remove them from the fire, and when cold, the carbonic acid of the chalk will have been decomposed, and the BLACK CHARCOAL, the basis of the acid, may be easily perceived amongst the materials. See page 280.

128. Place a lighted wax taper within a narrow glass jar, then take a jar or phial of carbonic acid gas, and cautiously pour it into the jar containing the taper. This being an *invisible* gas, the operator will appear to invert merely an *empty* vessel, though the taper will be as effectually and instantaneously EXTINGUISHED as if water itself had been used. See note *, page 281.

129. Make a little charcoal perfectly dry, pulverize it very fine, and put it into a warm tea-cup. If some strong nitrous acid be now poured upon it, COMBUSTION and INFLAMMATION will immediately ensue. See page 266.

130. If strong nitrous acid be poured upon a small quantity of a mixture of oxymuriate of potass and phosphorus, FLASHES OF FIRE will be emitted at intervals for a considerable time. See page 220.

131. Put a bit of phosphorus into a small phial, then fill it one-third with boiling olive oil, and cork it close. Whenever the stopper is taken out in the night, LIGHT WILL BE EVOLVED sufficient to show the hour upon a watch.

132. Let sulphuric acid be poured into a saucer upon some acetate of potass. Into another saucer put a mixture of about two parts quick-lime, and one of sal-ammoniac, both in powder, adding to these a *very small* quantity of boiling water. Both saucers while separate will yield *invisible* gases: but the moment they are brought close together, the operator will be

ENVELOPED IN VERY VISIBLE VAPOURS. Muriate of soda, in this experiment, may be substituted for acetate of potass. See page 166.

133. Take a glass tube with a bulb in form of a common thermometer; fill it with cold water, and suspend it by a string. If the bulb be frequently and continually moistened with pure sulphuric ether, the water will presently be FROZEN, EVEN IN SUMMER. See note, page 97.

134. Dissolve five drachms of muriate of ammonia, and five drachms of nitre, both finely powdered, in two ounces of water. A thermometer immersed in the solution will show that the temperature is reduced below 32°. If a thermometer tube, filled with water, be now suspended within it, the WATER will soon be AS EFFECTUALLY FROZEN as in the last experiment. See last note, page 73.

135. Procure a phial with a glass stopper accurately ground into it; introduce a few copper filings, then entirely fill it with liquid ammonia, and stop the phial so as to exclude all atmospheric air. If left in this state, no solution of the copper will be effected. But if the bottle be afterwards left open for some time, and then stopped, the metal will dissolve, and the solution will be colourless. Let the stopper be now taken out, and the fluid will become blue, beginning at the surface, and spreading gradually through the whole. If this blue solution has not been too long exposed to the air, and fresh copper filings be put in, again stopping the bottle, the fluid will once more be deprived of its COLOUR, which it will RECOVER ONLY BY THE RE-ADMISSION OF AIR. These effects may thus be repeatedly produced. See note, page 363.

136. Pour concentrated nitric acid upon pieces of iron, and very little action will be seen: but if a few drops of *water* be added a most violent effervescence will immediately commence; the acid will be decomposed with rapidity, clouds of red nitrous gas will be evolved in abundance, and a perfect SOLUTION OF THE METAL effected.

137. Take any solution of iron, a chalybeate water for instance, and add a little succinate of ammonia; a precipitate will be immediately visible, being succinate of iron. By this test the QUANTITY of iron in any solution may be ACCURATELY ASCERTAINED. See page 241.

138. In like manner add sulphuretted hydrogen to a solution of lead, and a deep brown precipitate will be occasioned.

This is an effectual mode of DETECTING this and some other PERNICIOUS METALS. See Add. Notes, No. 31.

139. Melt sulphur in a small iron ladle, and carry it into a dark room in the state of fusion. If an ounce or two of copper filings be now thrown in, LIGHT WILL BE EVOLVED. See page 384.

140. Dissolve some quicksilver in nitrous acid, and drop a little of the solution upon a bright piece of copper. If it be then gently rubbed with a bit of cloth, the mercury will precipitate itself upon the copper, which will be completely silvered. This experiment is illustrative of the PRECIPITATION OF ONE METAL BY ANOTHER. See page 366.

141. If a little nitro-muriate of gold be added to a fresh solution of muriate of tin, both being much diluted with water, the gold will be precipitated of a purple colour, forming that beautiful pigment called POWDER OF CASSIUS. See note §, page 298.

142. Take a phial with a solution of sulphate of zinc, and another containing a little liquid ammonia, both transparent fluids. By mixing them, a curious phenomenon may be perceived:—the zinc will be immediately precipitated in a white mass, and if then shaken, almost as INSTANTLY REDISSOLVED.

143. If a colourless solution of galls be added to a solution of bismuth in nitric acid, equally colourless, a *brown* precipitate will be produced. This is a distinguishing CHARACTERISTIC OF THIS METAL. See page 339.

144. If a colourless solution of arsenic in nitric acid be poured into a colourless solution of copper, a *green* precipitate will be produced, forming an arseniate of copper similar to an ore found in the Cornish mines. These metals may be thus RECIPROCALLY DETECTED. See page 312.

145. If a spoonful of good alcohol and a little boracic acid be stirred together in a tea-cup, and then set on fire, they will produce a very beautiful GREEN FLAME. See note *, page 193.

146. If alcohol be inflamed in like manner with a little pure strontian in powder, or any of its salts, the mixture will give a CARMINE FLAME. See note ‖, page 132.

147. If barytes be used instead of strontian, we shall have a brilliant YELLOW FLAME. See text, page 131.

148. Alloy a piece of silver with a portion of lead, place the alloy *upon a piece of* charcoal, attach a blow-pipe to a gas

meter charged with oxygen gas, light the charcoal first with a bit of paper, and keep up the heat by pressing upon the machine. When the metals get into complete fusion, the lead will begin to burn, and very soon will be all dissipated in a white smoke, leaving the silver in a state of purity. This experiment is designed to show the FIXITY of the NOBLE METALS. See note ‖, page 330.

149. Fuse a small quantity of nitre in a crucible, and, when in complete fusion, throw pulverized coal into it by small quantities at a time. The carbonaceous matter will decompose the nitre, and the bituminous part will burn away without acting upon it. This experiment will exhibit a mode of ANALYSING COAL; for every 100 grains of nitre that are decomposed in this way, denote ten grains of carbon. See note *, page 222.

150. Burn a piece of iron wire in a deflagrating jar of oxygen gas, as directed page 376, and suffer it to burn till it goes out of itself. If a lighted wax taper be now let down into the gas, this will burn in it for some time, and then become extinguished. If ignited sulphur be now introduced, this will also burn for a limited time. Lastly, introduce a morsel of phosphorus, and combustion will also follow in like manner. These experiments show the RELATIVE COMBUSTIBILITY of different substances. See page 386.

151. If oxide of cobalt be dissolved in ammonia, a RED SOLUTION will be produced, different in colour from that of all other metallic oxides. See page 345.

152. If nickel be dissolved in nitric acid, a beautiful GREEN SOLUTION will be formed. The oxide of this metal is used to give a delicate grass green to porcelain. See page 333.

153. When colourless prussiate of potass is added to a solution of titanium, this metal will be precipitated also of a GREEN COLOUR.

154. Add a little colourless solution of galls to a clear solution of antimony in nitro-muriatic acid, and the metal will be precipitated of a PALE YELLOW COLOUR. See page 338.

155. If a solution of tungstate of potass be poured into a solution of the green sulphate of iron, a YELLOW PRECIPITATE will fall down. By this experiment the distinguishing characteristic of this metal is exhibited.

156. Add a few grains of oxymuriate of potass to a teaspoonful or two of alcohol, drop one or two drops of sul-

phuric acid upon the mixture, and the whole will BURST INTO FLAME, forming a very beautiful appearance. See page 220.

157. A mixture of oxymuriate of potass and arsenic furnishes a detonating compound, which takes fire with the utmost rapidity. The salt and metal, first separately powdered, may be mixed by the gentlest possible triture, or rather by stirring them together on paper with the point of a knife. If two long trains be laid on a table, the one of gunpowder and the other of this mixture, and they be in contact with each other at one end, so that they may be fired at once; the arsenical mixture burns with the RAPIDITY OF LIGHTNING, while the other burns with comparatively extreme SLOWNESS. See page 220.

158. Into an ale-glass of water put a few filings of zinc, and a small bit of phosphorus; then drop a little sulphuric acid upon the mixture by means of a glass tube, as described at No. 39, and phosphuretted hydrogen will presently be disengaged, which will INFLAME on rising to the SURFACE OF THE WATER. See page 256.

159. Take a small piece of phosphuret of lime, a little moistened by the air, and let a single drop of concentrated muriatic acid fall upon it. In this case phosphuretted hydrogen will also be evolved, accompanied by SMALL BALLS OF FIRE darting from the mixture, and the most intolerable fetid smell that can be conceived. See page 256.

160. If 20 grains of phosphorus, cut very small, and mixed with 40 grains of finely granulated zinc, be put into 4 drachms of water, and 2 drachms of concentrated sulphuric acid be added thereto, bubbles of inflamed phosphuretted hydrogen gas will quickly cover the whole surface of the fluid in succession, forming a real AQUEOUS FOUNTAIN OF FIRE. See pages 261 and 262.

161. If any light substance capable of conducting heat, be placed upon the surface of boiling water, and a bit of phosphorus be laid upon it, the heat of the water will be sufficient to set the PHOSPHORUS ON FIRE. See page 262.

162. If hot water be poured into a glass jar of cold water, it will remain on the *surface*; but if cold water be poured upon hot water, it will sink to the *bottom* of the vessel. This experiment may be rendered more obvious by colouring that portion of the water which is poured in. The design of this experiment is to show the CHANGE of the SPECIFIC GRAVITY of the *same* body, merely by the AGENCY of CALORIC.

163. If a solution of the green sulphate of iron be dropped into a nitro-muriate of gold, the last metal will be immediately precipitated. In this state it is often employed in GILDING CHINA. See page 298.

164. If flowers, or any other figures, be drawn upon a riband or silk with a solution of nitrate of silver, and the silk, moistened with water, be then exposed to the action of hydrogen gas, the silver will be revived, and the figures, firmly fixed upon the silk, will become visible, and shine with METALLIC BRILLIANCY. See page 367.

165. By proceeding in the same manner, and using a solution of gold in nitro-muriatic acid, silks may be PERMANENTLY GILT at a most insignificant expense, and will exhibit an appearance the most beautiful that can be conceived. See page 367.

166. To a similar solution of gold add about a fourth part of ether; shake them together, and wait till the fluids separate; the upper stratum, or ethereal gold, is then to be carefully poured off into another vessel. If any polished steel instrument or utensil be dipped into this solution, and instantly plunged into water, the surface will have acquired a coat of pure gold, being a very elegant and economical mode of PRESERVING POLISHED STEEL FROM RUST. See note *, page 297.

167. If nitro-muriate of platina be mixed with a fourth part of its bulk of ether, and the mixture suffered to settle, the ethereal solution of platina may be decanted as in the preceding experiment. Polished brass, and some other metals immersed in this solution, will be COVERED WITH A COAT OF PLATINA. This process may be applied to many useful purposes. See notes, page 305.

168. If a small thermometer be placed in a glass vessel containing about an ounce of a solution of soda; on adding a sufficient quantity of muriatic acid to saturate the soda, the mercury in the thermometer will expand; affording an instance of HEAT being produced by THE FORMATION OF A SALT. See page 77.

169. Let the last experiment be repeated, with the *carbonate* of soda instead of pure soda; the mercury will now sink in the thermometer. Here, though the SAME KIND OF SALT is formed, COLD IS PRODUCED. See note *, page 96.

170. Fill a thermometer tube with tepid water, and immerse it in a glass vessel of water of the same temperature, containing a mercurial thermometer. If the whole be now placed in

a bed of snow, or in a frigorific mixture, the water in the tube will suffer a progressive diminution of volume, until it arrives at about 40°; it will then begin to expand gradually until it becomes solid. This shows how ICE is enabled to SWIM ON THE SURFACE OF WATER. See pages 93 to 95.

171. Another example on this subject may be shown. Fill a thermometer tube with cold water, at about 32°, and immerse it in a vessel of warm water. In this case, the water in the tube will contract in volume till it arrives at about 42°; when it will appear for a time nearly stationary. If the heat be now continued, the effect will be reversed, for the water in the tube will *expand* as its temperature is increased. This is a curious instance of a CHEMICAL ANOMALY. See note *, page 94.

172. It is an interesting experiment to place a glow-worm within a jar of oxygen gas, in a dark room. The insect will shine with much greater brilliancy than it does in atmospheric air, and appear more alert As the luminous appearance depends on the will of the animal, this experiment probably affords an instance of the STIMULUS which this gas communicates to the ANIMAL SYSTEM. See Additional Notes, No. 6.

173. Prepare a very dilute and colourless solution of platina by dropping a small quantity of the nitro-muriate of that metal into a glass of water. If a single drop of the solution of muriate of tin be added to this, a bright red precipitate will be instantly produced. A more DELICATE TEST than this of any metal cannot be conceived. See page 303.

174. If a morsel of the dried crystals of nitrate of silver (not the lunar caustic) be laid on a piece of burning charcoal, the metallic salt will immediately deflagrate, throw out the most beautiful scintillations that can be imagined, and the surface of the CHARCOAL will be richly COATED WITH METALLIC SILVER. See page 367.

175. To a colourless solution of nitrate of mercury, add an equally colourless solution of sub-borate of soda. This will produce a double decomposition, and form a bright yellow precipitate of borate of mercury; giving an instance of DIFFERENCE OF COLOURS IN METALS, by their union WITH DIFFERENT ACIDS. See page 356.

176. Into a diluted solution of sulphate of copper, pour a little liquid caustic ammonia. This will precipitate the copper of a blueish white. During its examination, however, the

precipitate will be re-dissolved, and a beautiful blue liquid called AQUA CELESTIS, will be the result. See page 314.

177. If one grain of dry nitrate of bismuth be previously mixed with a grain of phosphorus, and then rubbed together in a metallic mortar, a LOUD DETONATION will be produced. See Additional Notes, No. 22.

178. Write on paper with a solution of nitrate of bismuth; when this is dry the writing will be invisible; but if the paper be immersed in water, it will be DISTINCTLY LEGIBLE. See page 340.

179. A letter written with a diluted solution of bismuth, becomes, when dry, illegible; but a feather dipped in a solution of sulphuret of potass, will instantly blacken the oxide, and REVIVE THE WRITING. See note †, page 340.

180. Drop a piece of phosphorus about the size of a pea into a tumbler of hot water, and from a bladder, furnished with a stop cock, force a stream of oxygen gas directly upon it. This will afford the most BRILLIANT COMBUSTION UNDER WATER that can be imagined. See page 262.

181. Paste a slip of litmus paper within a glass jar, near the bottom, then fill the jar with water, and invert it on the shelf of a pneumatic trough. If as much nitrous gas, previously well washed, be passed into the jar as will displace the water below the level of the paper, the colour of the litmus paper will still remain unaltered; but on passing up atmospheric air it will immediately be reddened; showing THE FORMATION OF AN ACID, by the MIXTURE OF TWO GASES. See page 372.

182. Take a few grains of citric acid, and twice as much dry carbonate of potass, or of soda, both in powder; mix them, and put them into a dry glass. No chemical change will take place in either of these salts, but the moment water is poured upon them, an effervescence will ensue; affording an instance of the necessity of WATER to promote SOME CHEMICAL DECOMPOSITION. See page 25.

183. Dissolve a few crystals of nitro-muriate of gold in about 8 times their weight of pure water; place a thin slip of charcoal in the solution, and heat the whole by means of a bath. When the solution has acquired nearly a boiling heat the gold will precipitate itself on the charcoal in the form of metallic splendour, forming a singular and beautiful appearance. This experiment is designed to show that Mr

become INSOLUBLE, the moment they IMPART THEIR OXYGEN to foreign bodies. See page 296.

184. Proceed as in the last experiment, and submit the vessel with its contents to the rays of the sun. Here the metal will be reduced, and the charcoal as effectually gilt as before. This is illustrative of the DE-OXIDIZING POWER OF THE SUN'S RAYS. See note, page 368.

185. Drop a little leaf gold into nitro-muriatic acid, and it will instantly di-appear. This experiment is designed to show the great SOLUBILITY OF THE METALS, when submitted to a proper menstruum. See page 297.

186. Pour a little purified nitric acid into one wine glass, and muriatic acid into another; and drop a little gold leaf into each. Here neither of these corrosive acids will act at all upon the metal, THE GOLD WILL REMAIN UNTOUCHED. Now pour the whole contents of the two glasses together, and the metal will di-appear, and be as effectually dissolved as in the last experiment. See note, page 297.

187. If a little metallic arsenic in powder be mixed with a few zinc filings, and then treated with diluted sulphuric acid, ARSENIATED HYDROGEN GAS may be collected, which burns with a peculiar kind of lambent white flame.

188. If a portion of this gas, issuing from a very small tube, be set on fire, and then immersed in a large glass receiver of oxygen gas, and the stream of arseniated hydrogen kept up by the pressure of the bladder, a BLUE FLAME of uncommon splendour will be produced. See note ¼, page 342.

189. Take an amalgam of lead and mercury, and another amalgam of bismuth, let these two SOLID AMALGAMS be mixed by triture, and they will INSTANTLY BECOME FLUID. See page 84.

190. Charge a small glass retort with strong muriatic acid, and insert its beak into a tubulated receiver, containing a little water; then into this receiver insert two small thermometers. the one immersed in the water, the other suspended above it. By applying the heat of a lamp to the retort, muriatic acid gas will be disengaged in abundance; and if the thermometers be examined, that which is suspended in the gas will be found to have risen only a FEW DEGREES, while that which was immersed in the cold water has acquired a BOILING HEAT. See page 77.

EXPERIMENTS.

Take a glass of cold water, pour a little sulphuric ether surface, and inflame it by a slip of lighted paper. er will burn for a considerable time and produce a large of flame, but when it is extinguished the water will l not to have increased in temperature. The design of eriment is to show that WATER is A BAD CONDUC- F CALORIC, and that when we wish to heat water, t ought not to be applied at its surface. See part of page 91.

Dip the bulb of a thermometer in melted rosin so as to glass with it, and suffer it to cool completely. If the a taper be now applied to the bulb so as to melt the e MERCURY in the thermometer will not rise at the h of the taper, but WILL actually be seen to CON- T AS THE ROSIN BECOMES LIQUID. See note *,

Put into a wine-glass about a scruple of the oxidized ese and potass, prepared as directed page 422, and an uantity of the same compound into another glass. On r hot, and on the other cold water. The HOT SO- N will exhibit a BEAUTIFUL GREEN colour; the ONE a DEEP PURPLE.

If a small portion of the same compound be put into

197. Into distilled water drop a little spiritous solution of soap, and no chemical effect will be perceived: but if some of the same solution be added to hard-water, a milkiness will immediately be produced, more or less, according to the degree of its impurity. This is a good method of ASCERTAINING THE PURITY OF SPRING WATER. See note *, page 213.

198. If a little pure WHITE calomel be rubbed in a glass mortar with a little colourless solution of caustic ammonia, the whole will become INTENSELY BLACK. See page 356.

199. A little of the solution of sulphate of manganese being exposed in a glass phial to the light of the sun, its rose colour will entirely fade. This is another experiment to show the DE OXIDIZING POWER OF THE SUN'S RAYS. If the phial be removed into a dark room, the original COLOUR of the solution will be RESTORED. See note †, page 367.

200. Dissolve about a drachm of pulverized sulphate of copper in a little boiling water, and an equal quantity of powdered muriate of ammonia in a separate vessel, in hot water. By mixing the contents of the two glasses, a quadruple salt will be formed, which gives a YELLOW colour to the solution WHILE HOT, and becomes GREEN WHEN COLD.

201. Mix three grains of sulphur with nine grains of dry nitrate of silver, and lay the mixture in a small heap on an anvil, or on any piece of solid metal. If the mixture be now struck smartly with a *cold* hammer, the sulphur will inflame, but no detonation will ensue. This is an instance of a METALLIC SALT being decomposed, and a combustible substance INFLAMED BY PERCUSSION.

202. If the experiment be repeated, and the mass be struck with a *hot* hammer, THE MIXTURE DETONATES, and the SILVER IS REDUCED.

203. Pour a solution of nitrate of silver into a glass vessel, and immerse a few slips of copper in it. In a short time a portion of the copper will be dissolved, and all the silver precipitated in a metallic form. If the solution, which now contains copper, be decanted into another glass, and pieces of iron added to it, this metal will then be dissolved, and the copper precipitated, yielding a striking example of PECULIAR AFFINITIES. See note §, page 366.

204. Melt a portion of grain tin, and pour it into a metallic cup. Allow it to cool till it is congealed to some depth, then pierce the solid crust, and carefully pour out that portion which is still liquid. If what remains in the vessel be suffered to cool entirely, it will present RHOMBOIDAL CRYSTALS of considerable size, formed by the assemblage of a great number of small needles longitudinally united. See note †, page 236, and page 253.

205. Treat silver in the same way, and we shall procure a metallic mass crystallized in QUADRANGULAR OR OCTAHEDRAL PRISMS. *These two experiments will succeed better if the metal be poured into a vessel with an orifice in the bottom, which must be stopped with a proper plug, and this removed as soon as the upper crust hardens; the liquid metal will then run out, and that which is congealed will exhibit a regular crystallization.*

206. Form an amalgam with four parts of silver leaf and two of mercury, and dissolve this amalgam in diluted nitric acid. Then add water to the solution, equal to 30 times the weight of the metals employed, and put the whole aside for use. If an ounce of this solution be at any time poured into a phial, and a small piece of soft amalgam of silver be dropt in, filaments of reduced silver will shoot from it, and extend upwards, in the form of a shrub. The appearance of arborescence is called THE TREE OF DIANA. See page 361.

207. If two parts of sulphate of copper, and three of carbonate of ammonia, (the one a blue, the other a white salt,) be rubbed together in a glass mortar till the carbonic acid be expelled, the mass will become soft and humid, and when dried, forms a crystalline powder of a most beautiful DEEP VIOLET colour. This compound was formerly called CUPRUM AMMONIACUM.

208. If a flat bar of iron be hammered briskly on an anvil, its temperature will soon be so increased, that a piece of phosphorus laid upon it would instantly be inflamed. This experiment is designed to show that CALORIC may be EVOLVED merely BY PERCUSSION; and that, when evolved, it is as active and energetic as though it had never been latent. See page 71.

209. If a little colourless and recently prepared muriate of tin be poured into a rich GREEN solution of muriate of copper, the copper will be deprived of a portion of its oxygen, and a WHITE MURIATE PRECIPITATED. See the last note, page 325.

210. Into the phial containing the white muriate of the last experiment, pour a little muriatic acid. The precipitate will quickly be dissolved, and THE SOLUTION WILL BE COLOURLESS. See page 363.

211. Procure some solution of sulphate of iron at the *minimum* of oxidizement, by digesting iron filings with the common sulphate. Into this, when filtered, drop a little of the solution of prussiate of potass, and a WHITE PRUSSIATE OF IRON will be precipitated. See note ‖, page 356.

212. If a very little colourless nitric acid be added to a solution of sulphate of iron prepared as in the last experiment, the addition of the prussiate of potass will produce not the white, but the BLUE PRUSSIATE OF IRON. See page 356, and note ‡, page 360.

213. Pour some pure nitric acid on the black oxide of manganese, and no solution will be effected. But if a little sugar be added, the SUGAR will ABSTRACT a part of the OXYGEN from the oxide of manganese, and the acid will then be enabled to dissolve the metal. See note *, page 365.

214. Expose an ounce of nitric acid for an hour, in an open phial, to the direct rays of the sun, and pour another ounce of the same acid, that has been so exposed, into another phial. If a little of the black oxide of manganese be now put into each, THE OXIDE in the *first phial* will be DISSOLVED, while that in *the other* will NOT BE AFFECTED by the acid. See page 186, and note ‡, page 365.

215. If a piece of bright silver be dipped in a solution of sulphate of copper, it will come out unchanged: but if the blade of a clean penknife, or any piece of *polished* iron, be dipped in the same solution, the IRON will instantly put on the APPEARANCE OF COPPER. See note ‖, page 313.

216. Take the piece of silver, employed in the last experiment, hold it in *contact with the iron*, and then, in this situation, dip them into the same solution, and BOTH will be COVERED WITH COPPER.

217. Dissolve some oxide of nickel in caustic ammonia, which will produce a solution of a rich BLUE colour. By exposure to the air this gradually changes to a PURPLE, and lastly to a VIOLET. The addition of an acid will, however, convert the whole to a GREEN.

218. Take the GREEN solution of the last experiment, and pour caustic ammonia upon it. The original BLUE colour will now be reproduced.

219. Prepare a colourless solution of tartrate of potass and antimony (the common emetic tartar) and pour into it a little liquid sulphuretted hydrogen. This will combine with the metallic oxide, and form an ORANGE COLOURED precipitate.

220. Melt together equal parts of copper and antimony, the one a yellow, the other a white metal, and the alloy that results from this mixture will take the COLOUR OF THE VIOLET.

221. If the gray sulphuretted oxide of antimony be fused in a crucible, we procure a beautiful transparent glass, which is called the glass of antimony. This takes THE COLOUR OF THE HYACINTH.

222. When antimony is heated to whiteness in a crucible, and in this state agitated, in contact with the air, it inflames with a sort of explosion, and presents while burning a very singular kind of WHITE FLAME, forming what have been formerly called *argentine flowers*.

223. When antimony is well fused upon charcoal, and if, at the moment when its surface is not covered with any particle of oxide, we throw it suddenly upon the ground, the globules, into which it divides in its fall, BURN with a very LIVELY FLAME, throwing out on all sides BRILLIANT SPARKS, different from that of any other metal. See note, page 317.

224. Mix five or six grains of sulphuret of antimony with half its weight of oxymuriate of potass, and then, if a sudden stroke be given to the mixture, upon a steel-anvil, it fulminates with a loud report, emitting, according to Fourcroy, a FLAME as brilliant and RAPID AS LIGHTNING.

225. If alcohol contains muriate of magnesia, it has the property of burning with a REDDISH YELLOW FLAME.

226. Evaporate to dryness a solution of gold, made with nitro-muriatic acid, and dissolve the crystals in a sufficiency of pure water to prevent the crystallization of the metallic salt. Thoroughly moisten a little magnesia with this aqueous solution, and place the mixture in the sun's rays. A change of colour will soon be apparent. It will first take a FAINT VIOLET hue, and in a few hours the whole will have acquired a very DEEP PURPLE. See page 368 and 367.

227. Moisten a little magnesia with some of the solution as before, and then dry the mixture in the *dark*. If it be then submitted to the action of the sun's rays, it will acquire only a

FAINT VIOLET, even BY SEVERAL HOURS exposure. See note, page 363.

228. If the mixture employed in the last experiment be now thoroughly *wetted* with pure water, and again placed within the rays of the sun, its colour will RAPIDLY CHANGE, and will acquire a DEEP PURPLE approaching to CRIMSON. See page 363.

229. Moisten a piece of white riband with the aqueous solution of gold described at No 226, and dry it thoroughly in the dark: then suspend it in a clean, dry, trans-parent phial, and cork it close with a dry cork. Expose the riband, thus secured, to the strong light of a bright sun, for half an hour, and only a FAINT appearance of CHANGE OF COLOUR will be perceived.

230. Take the riband out of the phial that was employed in the last experiment, and *wet* it well with distilled water. If it be now exposed to the sun's rays, it will instantly CHANGE colour, and will quickly be stained of an INDELIBLE PURPLE. See note, page 362.

231. Dissolve dry nitrate of silver in pure water; add a little oil of turpentine, shake the mixture, and cork it close. Submit the phial with its contents to the heat of boiling water for an hour, when the metal will be revived, and the inside of the phial, where the oil reposed on the aqueous solution, will be beautifully SILVERED, the revived metal forming a METALLIC RING, extending quite round the phial. See page 367.

232. Immerse a slip of white silk in a solution of nitro-muriate of gold in distilled water, and dry it in the air. Silk thus prepared will not be altered by hydrogen gas: but if another piece of silk be dipped in the solution and exposed while *wet* to the same current of hydrogen gas, instant signs of metallic reduction will appear; the colour will change from yellow to green, and a brilliant film of REDUCED GOLD will soon glitter on its SURFACE.

233. If a piece of silk be immersed in a solution of nitrate of silver and dried in a dark place, and then submitted to hydrogen gas, the silver will not be reduced; but if exposed while *wet* to a stream of the same gas, the surface will quickly be coated with reduced silver; various colours, such as blue, purple, red, orange, and yellow, will accompany the reduction, and the THREADS of the SILK will look like SILVER WIRE. *During these experiments the silk should be constantly kept wet with distilled water*

231. Dissolve some crystals of muriate of tin in distilled water, then dip a piece of white silk in the solution, and dry it in the air. If this be now immersed in hydrogen gas, no change will be observed: but if it be exposed while *wet* to the same current of gas, the reduction will soon commence, attended with a great variety of beautiful colours, as **RED, YELLOW, ORANGE, GREEN,** and **BLUE,** variously intermixed.

233. Prepare a strong solution of phosphorus in sulphuric ether, and dip a piece of white silk in the solution; then, when the ether has evaporated, and the phosphorus begins to fume, apply a solution of nitro-muriate of gold, made by dissolving the crystals of that salt in distilled water; the silk will in an instant be covered with a SPLENDID coat of METALLIC GOLD.

236. Proceed as in the last experiment, and instead of the solution of gold, apply with a camel's-hair pencil, a solution of nitrate of silver. Here the silver will instantly be restored to its METALLIC BRILLIANCY, and frequently attended by SPANGLES of a beautiful BLUE.

237. [illegible] in the usual solution, [illegible] will only [illegible] the [illegible] will [illegible] METALLIC [illegible]

238. [illegible] of gold" says [illegible] PURPLE, [illegible] RED [illegible] CHEMICAL DOUBLETS of the [illegible]

239. With a [illegible] phosphorus previously [illegible] PHOSPHORUS will become covered with [illegible]

239. If a piece of white SILK is dipped in an aqueous solution of nitro-muriate of gold and exposed while wet to sulphurous acid gas, the whole piece will in a few seconds be

covered with a coat of REDUCED GOLD, which remains PERMANENT.

241. If a piece of white silk be immersed in an aqueous solution of nitrate of silver, thoroughly dried in the dark, and then exposed to sulphurous acid vapours, it will suffer no change; nor, if it be wetted with *alcohol* and then replaced in the vapour, will any sign of reduction appear; but if it be wetted with pure *water*, and then exposed to the vapour, METALLIC SILVER will immediately be seen on its surface.

A glass funnel is a convenient apparatus for these experiments. The silk may be suspended by a thread passed through it, and made fast to the funnel with a cork. The funnel is then to be placed on a table, and by moving it a little over the edge of the table, a lighted match may be readily introduced, and when the glass is full of vapour the match may be withdrawn. The vapour is confined by sliding the funnel back upon the table; and thus the phenomena of the experiment may be easily observed.

242. Dip a piece of white calico in an aqueous solution of acetate of lead, and then drop a little solution of sulphuret of potass upon it. If this be now placed in the palm of the hand, the LEAD will be observed gradually to revive, and will soon be reduced to its METALLIC STATE.

243. Dissolve some sulphuret of potass in alcohol, and immerse a slip of white silk in the solution. If a drop of an aqueous solution of sulphate of manganese be now applied, films of METALLIC MANGANESE, bright as silver, will instantly appear.

244. If a bit of silk be immersed in diluted acetate of lead, and exposed while *wet* to a stream of sulphuretted hydrogen gas, a brown tinge will instantly diffuse itself, like a passing shadow, over the whole surface of the silk, accompanied with a bright coat of REDUCED LEAD, resembling silver.

245. If a piece of silk be immersed in an aqueous solution of muriate of tin, and exposed while *wet* to a stream of the same gas, REDUCED TIN of great brightness will immediately cover the surface, and in a little time this will be accompanied by various colours, such as BLUE, ORANGE, and PURPLE.

246. A piece of silk, treated in the same way, but dipped in an aqueous solution of muriate of arsenic, will be covered with resplendent METALLIC ARSENIC, attended with a CITRON YELLOW COLOUR.

247. Prepare two glasses of very dilute nitrate of copper; into one drop a little liquid ammonia, and into the other some diluted arseniate of potass. The addition of these two *colourless* solutions will produce very different effects; for the one glass will have an abundant precipitate of a beautiful GRASS GREEN, and the other a precipitate of a brilliant SAPPHIRE BLUE.

For the following Experiments I am indebted to the polite communication of Sir Humphry Davy, Professor of Chemistry at the Royal Institution.

248. Take a small piece of pure potash, gently breathe on its surface, and place it on an insulated plate connected with the negative side of a powerful galvanic battery in a state of intense activity. Then bring a metallic wire from the positive side of the battery in contact with the upper surface of the alkali, and soon a very vivid action will be observed. Small globules, having a high metallic lustre, and of the appearance of quicksilver, will be seen, some of which will burn with explosion and a bright flame as soon as they are formed. Thus POTASH may be DECOMPOSED AND ITS metallic BASE RENDERED VISIBLE in a separate state.

[illegible] the [illegible] substance formed in the last experiment, [illegible] heat it very hot, and confine it in a [illegible] vessel containing oxygen gas. Here a rapid combustion, like that of [illegible], will be produced, and the metallic [illegible] will be converted into a white and solid mass, which will be found to be REGENERATED PURE POTASH.

Take a small piece of potassium within a dry wine-glass [illegible] to acquire an idea of its specific gravity pour [illegible] alcohol, ether, or naphtha upon it; when, quitting the bottom of the glass, it will immediately rise to the surface of the liquid, it being, notwithstanding its metallic appearance, the LIGHTEST FLUID BODY KNOWN.

250. If a little potassium be dropped into a jar of oxymuriatic gas, it BURNS SPONTANEOUSLY, and emits a

A VOCABULARY

OF

CHEMICAL TERMS.

A.

ACETATES. Salts formed by the combination of any base with the acetic acid. See page 229.

ACIDS. For the nature of acids, see page 170.

——— *oxygenized.* Acids combined with an additional quantity of oxygen, for particular purposes. The oxy muriatic acid used in bleaching is an instance of this superoxygenizement. See page 182.

——— *hyperoxygenized.* Acids which are oxygenized to a maximum. See page 220.

ACIDULES. A term applied to the natural combination of some acids with a portion of potash. The oxalic acid and the tartaric are the only acids that have hitherto been found in this state of semi-saturation. See page 215.

AËRIFORM *fluids.* Fluid substances combined with an additional portion of caloric sufficient to give them the gaseous form. See *Gas.*

AFFINITY, *chemical.* A term used to express that peculiar propensity which different species of matter have to unite with each other, or with portions of matter of their own species. See chap. 13.

——— *of aggregation.* A force by which two bodies of the *same* kind tend to combine, and by which an aggregate is formed without the *chemical* properties of the substances being at all changed. See page 394.

——— *of composition.* A force by which substances of *different* kinds unite, and by which matter is formed whose properties are different from those of the bodies before their combination. This attraction is stronger in proportion as the nature of the bodies is different, between which it is exerted. See page 395.

EGATES. Substances whose parts are united by cohesive, and not by chemical attraction. See *Affinity of aggregation.* See page 391.

MEN. The modern name for coagulable lymph. It is that peculiar animal substance which forms the serum of the blood, the white of eggs, and other compounds.

HOL. Rectified spirit of wine. When good, its specific gravity is only 0.836. See page 287.

BIC. The term formerly given to the still used by chemists for their distillations.

LIES. Peculiar substances which have an urinous, burning, and caustic taste, and a strong tendency to combination. When united with acids they form mild alkaline salts. See page 147.

YS. A combination of any two metals, except mercury, is called an alloy. Thus gold is alloyed either with silver or copper, for the purposes of coinage.

VIAL By alluvial depositions is meant the soil which has been formed by the destruction of the mountains, and the washing down of their particles by torrents of water. See page 247.

.GAM. A combination or mixture of mercury with any other metal, is called an amalgam.

)NIACAL *salts.* Salts formed by the union of an acid

ATMOSPHERES. We use this term to express the degree of additional pressure given to fluids Thus, if, in order to impregnate water with any of the gases, I give it a pressure of 15lbs. upon every square inch of surface, I am said to give *one* atmosphere; if 30lbs. *two* atmospheres, &c. &c. See page 51.

ATTRACTION. Chemical attraction is a term synonymous with *affinity;* which see.

AZOTE. A name given by the French chemists to *nitrogen*, to which, being the most proper, the reader is referred.

B.

BALLOON. A term given by the French to their spherical chemical receivers.

BALSAMS. Certain aromatic resinous substances, which are obtained from some trees by incisions. Of this kind are the Canada balsam, the balsam of Copaiva, the balsam of Tolu, &c.

BAROMETER. An instrument which shows the variation of the pressure of the atmosphere, by the rise or fall of a column of mercury in a glass tube attached to a graduated plate. See note ‡, page 38.

BASE. A chemical term, usually applied to denote the earth, the alkali, or the metal which is combined with an acid to form a salt.

BATHS. Vessels for distillation or digestion, contrived to transmit heat gradually and regularly.

——— *sand.* Vessels filled in part with dry sand, in which those retorts are placed which require a greater heat than can be given by boiling water. In large works, iron plates are used instead of vessels of capacity. They are often called *sand-baths.*

——— *water.* Vessels of boiling water, in which other vessels containing the matters to be distilled or digested are placed, in order that the same heat may be kept up throughout the whole of any particular process.

BENZOATES. Salts formed by the combination of any base with the benzoic acid.

BITTERN. The mother-liquor which remains after the crystallization of muriate of soda (sea-salt) It generally contains sulphate of magnesia, and a small portion of sulphate of soda.

BITUMEN. A generic term, applied to a variety of fossil inflammable substances. See notes, page 271.

BLOW-PIPE. An instrument to increase and direct the flame of a lamp for the analysis of minerals, and for other chemical purposes.

BOLT-HEAD. A round chemical vessel with a long neck, usually employed for digestions. It is also called a matrass.

BORATES. Salts formed by the combination of any base with the acid of borax. See page 227.

BUTTON. A name given to the small round piece of metal which is found at the bottom of a crucible after a metallic ore or an oxide of metal has been reduced.

C.

CALCAREOUS. A chemical term formerly applied to describe chalk, marble, and all other combinations of lime with carbonic acid. See page 133.

CALCINATION. The application of heat to saline, metallic, or other substances; so regulated as to deprive them of moisture, &c. and yet preserve them in a pulverulent form.

CALORIC. The chemical term for the matter of heat.

——— *free.* Is caloric in a separate state, or, if attached to other substances, not *chemically* united with them. See page 74.

——— *latent.* Is the term made use of to express that portion of caloric which is chemically united to any substance, so as to become a *part* of the said substance. See page 75.

CALORIMETER. An instrument for ascertaining *the quantity* of caloric disengaged from any substance that may be the object of experiment. See page 79.

CALX. An old term made use of to describe a metallic oxide.

CAMPHORATES. Salts formed by the combination of any base with the camphoric acid. See page 232.

CAPILLARY. A term usually applied to the rise of the sap in vegetables, or the rise of any fluid in very small tubes; owing to a peculiar kind of attraction, called capillary attraction.

CAPSULES. Are small saucers of clay for roasting samples of ores, and for smelting them to ascertain their value.

CAPUT MORTUUM. A term signifying *dead-head*, being that which remains in a retort after distillation to dryness. See *Residuum*, which is the modern term.

CARBON. The basis of charcoal. See page 264.

CARBONATES. Salts formed by the combination of any base with carbonic acid. See page 223.

CARBURETS. Compound substances, of which carbon forms one of the constituent parts. Thus plumbago, which is composed of carbon and iron, is called carburet of iron. See page 278.

CAUSTICITY. That quality in certain substances by which they burn or corrode animal bodies to which they are applied. It is best explained by the doctrine of chemical affinity. See note *, page 143.

CEMENTATION. A process by which metals are purified or changed in their qualities by heat, without fusion, by means of a composition called a cement, with which they are covered. Thus iron, by being kept a long time in a certain degree of heat, surrounded by charcoal powder, is converted into steel.

CHALYBEATE. A term descriptive of those mineral waters which are impregnated with iron. See *Martial*.

CHARCOAL. Wood burnt in close vessels; it is an oxide of carbon, and generally contains a small portion of salts and earth. Its carbonaceous matter may be converted by combustion into carbonic acid gas. See page 265.

CHATOYANT. A term much used lately by the French chemists to describe a property in some metallic and other substances of varying their colours according to the way in which they are held; as is the case with the feathers of some birds, which appear very different when seen in different positions.

CHERT. A term made use of in describing a species of siliceous stones, which are coarser and softer than the common silex. It is often found in large masses in quarries of limestone.

CHLORINE. A name lately given to the substance usually called oxymuriatic acid. Its compounds are called by the name of their bases with the ending of *ane*. As phosphorane, sulphurane, &c.

CHROMATES. Salts formed by the combination of any base with the chromic acid. See page 194.

CITRATES. Salts formed by the combination of any base with citric acid. See page 231.

COAL. A term applied to the residuum of any dry distillation of animal or vegetable matters. See page 269.

COHESION. A force inherent in all the particles of all substances, excepting light and caloric, which prevents bodies from falling in pieces. See *Affinity*.

COHOBATION. When a distilled fluid is poured again upon the matter from which it was distilled, in order to make it stronger, it is called cohobation. It is not much practised by modern chemists.

COLUMBATES. Salts formed by the combination of any base with the columbic acid. See page 206.

COMBINATION. A term expressive of a true *chemical* union

of two or more substances; in opposition to mere mechanical mixture.

COMBUSTIBLES. Certain substances which are capable of combining more or less rapidly with oxygen. They are divided by chemists into simple and compound combustibles. See page 375.

COMBUSTION. The act of absorption of oxygen by combustible bodies from atmospheric or vital air. The word decombustion is sometimes used by the French writers to signify the opposite operation. See page 375.

COMMINUTION. The reduction of hard bodies into small particles. By this process the heaviest substances may be made to float in the lightest fluids.

CONCENTRATION. The act of increasing the specific gravity of bodies. The term is usually applied to fluids which are rendered stronger by evaporating a portion of the water which they contain.

CONDENSATION. The act of bringing the component parts of vapour, or gas, nearer together by pressure, or by cold. Thus atmospheric air may be condensed by pressure, and aqueous vapour by the subtraction of caloric, till it is converted into water.

CRUCIBLES. Vessels of indispensable use in chemistry in the various operations of fusion by heat. They are made of baked earth, or metal, in the form of an inverted cone.

CRYSTALLIZATION. An operation of nature, in which various earths, salts, and metallic substances, pass from a fluid to a solid state, assuming certain determinate geometrical figures. See page 234.

——————— *water of.* That portion which is combined with salts in the act of crystallizing, and becomes a *component* part of the said saline substances. See page 237.

CUPEL. A vessel made of calcined bones, mixed with a small proportion of clay and water. It is used whenever gold and silver are refined by melting them with lead. The process is called cupellation.

D.

DECOMBUSTION. Synonymous with Deoxidizement; which see.

DECOMPOSITION. The separation of the constituent principles of compound bodies by chemical means.

DECREPITATION. The sudden decomposition of salts attended with a crackling noise when thrown into a red-hot crucible, or on an open fire.

DEFLAGRATION. The vivid combustion that is produced whenever nitre, mixed with an inflammable substance, is exposed to a red heat. It may be attributed to the extrication of oxygen from the nitre, and its being transferred to the inflammable body; as any of the nitrates or oxygenized muriates will produce the same effect.

DELIQUESCENCE *of solid saline bodies*, signifies their becoming moist, or liquid, by means of water which they absorb from the atmosphere in consequence of their great attraction for that fluid. See page 238.

DELIQUIUM is the state of pot ash, or any deliquescent salt, when it has so far deliquesced by exposure to the air as to have become a liquid

DELITE. A term used by some of the French writers, signifying to break, by the action of the air, like a soft stone into layers. See Annales de Chimie, tom. xix. 79.

DEOXIDIZE (formerly Deoxidate.) To deprive a body of oxygen.

DEOXIDIZEMENT. A term made use of to express that operation by which one substance deprives another substance of its oxygen. It is called unburning a body by the French chemists.

DEPHLEGMATION is the act of separating the water from chemical liquors.

DEPURATION. The purging or separating any liquid in a state of purity from its fæces or lees.

DETONATION. An explosion with noise. It is most commonly applied to the explosion of nitre when thrown upon heated charcoal. See note †, page 221.

DIGESTION. The effect produced by the continued soaking of a solid substance in a liquid, with the application of heat.

DIGESTOR, *Papin's.* An apparatus for reducing animal or vegetable substances to a pulp or gelly expeditiously.

DISTILLATION. A process for separating the volatile parts of a substance from the more fixed, and preserving them both in a state of separation.

DOCIMASTIC ART. The art of assaying metals.

DUCTILITY. A quality of certain bodies, in consequence of which they may be drawn out to a certain length without fracture. See page 291.

DULCIFICATION. The combination of mineral acids with alcohol. Thus we have dulcified spirit of nitre, dulcified spirit of vitriol, &c.

E.

EDULCORATION. Expressive of the purification of a substance by washing with water.

EFFERVESCENCE. An intestine motion which takes place in certain bodies, occasioned by the sudden escape of a gaseous substance.

EFFLORESCENCE. A term commonly applied to those saline crystals which become pulverulent on exposure to the air, in consequence of the loss of a part of the water of crystallization. See page 239.

ELASTICITY. A force in bodies, by which they endeavour to restore themselves to the posture from whence they were displaced by any external force. See page 42.

ELASTIC FLUIDS. A name sometimes given to vapours and gases. Vapour is called an *elastic* fluid; gas, a *permanently* elastic fluid.

ELECTIVE ATTRACTIONS. A term used by Bergman and others to designate what we now express by the words chemical *affinity*; which see. When chemists first observed the power which one compound substance has to decompose another, it was imagined that the minute particles of some bodies had a *preference* for some other particular bodies; hence this property of matter acquired the term *elective* attraction. See chap. 13.

ELEMENTS. The simple, constituent parts of bodies which are incapable of decomposition; they are frequently called principles. See *Simple Substances.*

ELIQUATION. An operation whereby one substance is separated from another by fusion. It consists in giving the mass a degree of heat that will make the more fusible matter flow, and not the other.

ELUTRIATION. The operation of pulverizing metallic ores or other substances, and then mixing them with water, so that the lighter parts which are capable of suspension may be poured off, and thus separated from the grosser particles. Most of the metallic substances which are reduced to an impalpable powder are prepared by this process.

EMPYREUMA. A peculiar and indescribably disagreeable smell, arising from the burning of animal and vegetable matter in close vessels.

EOLIPILE. A copper vessel with a small orifice, and partly filled with water. It is made hot, in order that the vapour of the water may rush out with violence, and carry a stream of air with it to increase the intensity of fires. It is an instrument of great antiquity.

ESSENCES. What are called essences, in chemistry and pharmacy, are the essential oils obtained by distillation from odoriferous vegetable substances.

ESSENTIAL SALTS. The saline substances found in plants, and which are held in solution by the water wherein they are infused. They are obtained by evaporation and cooling.

ETHERS. Volatile liquids formed by the distillation of some of the acids with alcohol.

EVAPORATION. The conversion of fluids into vapour by heat. This appears to be nothing more than a gradual solution of the aqueous particles in atmospheric air, owing to the chemical attraction of the latter for water.

EUDIOMETER. An instrument invented by. Dr. Priestley for determining the purity of any given portion of atmospheric air. The science of investigating the different kinds of gases is called *eudiometry.*

EXPRESSION. A term used in pharmacy, denoting the act of forcing out the juices and oils of plants by means of a press. By a similar term the *expressed* are distinguished from the *essential* oils.

EXSICCATION. The act of drying moist bodies. It is effected in two ways; by exhaling the aqueous particles by the application of heat or atmospheric air, and by absorbing the moisture with soft and spongy substances. Thus, small matters are dried by chemists with bibulous paper; and larger masses, by spreading them on tablets of chalk.

EXTRACTS. The soluble parts of vegetable substances, first dissolved in spirit or water, and then reduced to the consistence of a thick syrup, or paste, by evaporation.

F.

FAT. An oily concrete animal substance, composed of oil, sebacic acid, and carbon.

FERMENTATION. A peculiar spontaneous motion, which takes place in all vegetable matter when exposed for a certain time to a proper degree of temperature. For the changes which are effected by saccharine fermentation, see page 286.

FIBRINE. That white fibrous substance which is left after freely washing the coagulum of the blood, and which chiefly composes the muscular fibre.

FILTRATION. A chemical process for the depuration of liquid substances. Bibulous paper supported by a funnel is commonly made use of; but for expensive liquors chemists generally use a little carded cotton lightly pressed in the tube of a glass funnel. The valuable

concentrated acids should be filtered through pounded glass.

FIXITY. A term applicable to that property of some bodies of bearing a great heat without being volatilized.

FLOWERS. In chemical language, are solid dry substances reduced to a powder by sublimation. Thus we have flowers of arsenic, of sal ammoniac, of sulphur, &c. which are arsenic, sal ammoniac, and sulphur unaltered except in appearance.

FLUATES. Salts formed by the combination of any base with fluoric acid. See page 226.

FLUIDITY. A term applied to all liquid substances. Solids are converted to fluids by combining with a certain portion of caloric. See page 27.

FLUX. A substance which is mixed with metallic ore, or other bodies to promote their fusion; as an alkali is mixed with silex, in order to form glass.

FOSSIL. See *Mineral*, with which it is synonymous.

FULIGINOUS. A term sometimes made use of in describing certain vapours which arise in chemical operations, having the thick appearance of smoke.

FULMINATION. Thundering or explosion with noise. We have fulminating silver, fulminating gold, and other fulminating powders, which explode with a loud report by friction, or when slightly heated See page 310.

FURNACES. Chemical vessels of various forms for the fusion of ores, or other operations which require heat.

———— *blast.* Are built for making iron, smelting ores, &c. They are so contrived that their heat is much increased by means of powerful bellows. A blacksmith's forge is a kind of blast furnace.

———— *wind.* Chemical furnaces for intense heat, so constructed that they draw with great force, without the use of bellows.

FUSION. The state of a body which was solid in the temperature of the atmosphere, and is now rendered fluid by the artificial application of heat.

G.

GALLATES. Salts formed by the combination of any base with gallic acid. See page 200.

GALVANISM. A new science which offers a variety of phenomena, resulting from different conductors of electricity placed in different circumstances of contact; particularly the nerves of the animal body. See page 72.

GANGUE. A term made use of to denote the stony matter which fills the cavities, and accompanies the ores in the veins of metals.

GAS. All solid substances, when converted into permanently elastic fluids by caloric, are called gases. See page 56.

GASEOUS. Having the nature and properties of gas.

GASOMETER. A name given to a variety of utensils and apparatus contrived to measure, collect, preserve, or mix the different gases. An apparatus of this kind is also used for the purposes of administering pneumatic medicines.

GASOMETRY. The science of measuring the gases. It likewise teaches the nature and properties of these elastic fluids.

GELATINE. A chemical term for animal gelly. It exists particularly in the tendons and the skin of animals.

GLASS. Some metallic oxides, when fused, are called *glass*. They have somewhat of resemblance to common glass.

——— *phosphoric*. A vitreous, insipid, insoluble substance, procured by boiling down phosphoric acid to a syrup, and then fusing it by an increased heat.

——— *gall*. See *Sandiver*.

GLUTEN. A vegetable substance somewhat similar to animal gelatine. It is the gluten in wheat flour which gives it the property of making good bread, and adhesive paste. Other grain contains a much less quantity of this nutritious substance.

GRADUATION. A process by evaporation, of bringing fluids to a certain degree of consistence, in order to separate more easily the substances they hold in solution.

———. The division of a scale or measure into decimal, or other regular parts.

GRAIN. The *smallest* weight made use of by chemical writers. Twenty grains make a scruple; 3 scruples a drachm; 8 drachms, or 480 grains, make an ounce; 12 ounces, or 5760 grains, a pound troy. The *avoirdupois* pound contains 7000 grains.

GRANULATION. The operation of pouring a *melted* metal into water, in order to divide it into small particles for chemical purposes. Tin is thus granulated by the dyers before it is dissolved in the proper acid.

GRAVITY. That property by which bodies move towards each other, in proportion to their respective *quantities* of matter. This is the property by which bodies fall to the earth. See chap. 13.

GRAVITY *specific.* This differs from absolute gravity in as much as it is the weight of a given measure of any solid or fluid body, compared with the same measure of distilled water. It is generally expressed by decimals. See page 31.

GUMS. Mucilaginous exudations from certain trees. Gum consists of lime, carbon, oxygen, hydrogen, and nitrogen, with a little phosphoric acid.

H.

HEAT, *matter of.* See *Caloric.*

HEPAR. The name formerly given to the combination of sulphur with alkali. It is now called sulphuret of potass, &c. as the case may be.

HEPATIC *gas.* The old name for sulphuretted hydrogen.

HERMETICALLY. A term applied to the closing of the orifice of a glass tube, so as to render it air-tight. Hermes, or Mercury, was formerly supposed to have been the inventor of chemistry; hence a tube which was closed for chemical purposes was said to be Hermetically or chemically sealed. It is usually done by melting the end of the tube by means of a blow-pipe.

HYDROGEN. A simple substance; one of the constituent parts of water. See page 251.

———— *gas.* Solid hydrogen united with a large portion of caloric. It is the lightest of all the known gases. Hence it is used to inflate balloons. It was formerly called inflammable air.

HYDRO-CARBONATES. Combinations of carbon with hydrogen are described by this term. Hydro-carbonate gas is procured from moistened charcoal by distillation. See page 256.

HYDROGENIZED *sulphurets.* Certain bases combined with sulphuretted hydrogen.

HYDRO-OXIDES. Metallic oxides combined with water.

HYDROMETERS. Instruments for ascertaining the specific gravity of spirituous liquors or other fluids.

HYGROMETERS. Instruments for ascertaining the degree of moisture in atmospheric air.

HYPEROXYGENIZED. A term applied to substances which are combined with the largest possible quantity of oxygen. We have muriatic acid, oxygenized muriatic acid, and hyperoxygenized muriatic acid. The latter can be exhibited only in combination. See page 220.

I.

INCINERATION. The burning of vegetables for the sake of their ashes. It is usually applied to the burning of kelp on the sea-coast for making mineral alkali.

INFLAMMATION. A phenomenon which takes place on mixing certain substances. The mixture of oil of turpentine with strong nitrous acid is an instance of this peculiar chemical effect.

INFUSION. A simple operation to procure the salts, juices, and other virtues of vegetables by means of water.

INSOLATION. A term sometimes made use of to denote that exposure to the sun which is made in order to promote the chemical action of one substance upon another.

INTEGRANT *particles*. See note *, page 249.

INTERMEDIATES. A term made use of when speaking of chemical affinity. Oil, for example, has no affinity for water unless it be previously combined with an alkali; it then becomes soap, and the alkali is said to be the *intermedium* which occasions the union.

K.

KALI. A genius of marine plants which is burnt to procure mineral alkali by afterwards lixiviating the ashes. See page 151.

L.

LABORATORY. A room fitted up with apparatus for the performance of chemical operations.

LACTATES. Salts formed by the combination of any base with lactic acid. See page 200.

LAKES. Certain colours made by combining the colouring matter of cochineal, or of certain vegetables, with pure alumine, or with oxide of tin, zinc, &c.

LAMP, ARGAND'S. A kind of lamp much used for chemical experiments. It is made on the principle of a wind furnace, and thus produces a great degree of light and heat without smoke.

LENS. A glass, convex on both sides, for concentrating the rays of the sun. It is employed by chemists in fusing refractory substances which cannot be operated upon by an ordinary degree of heat. See note, page 89.

LEVIGATION. The grinding down of hard substances to an impalpable powder on a stone with a muller, or in a mill adapted to the purpose.

LIQUEFACTION. The change of a solid to the state of a fluid, occasioned by the combination of caloric. See page 28.

LITHARGE. An oxide of lead which appears in a state of vitrification. It is formed in the process of separating silver from lead. See note †, page 330.

LIXIVIATION. The solution of an alkali or a salt in water, or in some other fluid, in order to form a lixivium.

LIXIVIUM. A fluid impregnated with an alkali or with a salt.

LUTE. A composition for closing the junctures of chemical vessels to prevent the escape of gas or vapour in distillation. See Additional Notes, No. 54.

M.

MACERATION. The steeping of a solid body in a fluid in order to soften it, without impregnating the fluid.

MALATES. Salts formed by the combination of any base with malic acid. See page 190.

MALLEABILITY. That property of metals which gives them the capacity of being extended and flattened by hammering. It is probably occasioned by latent caloric. See page 291.

MARTIAL. An old term for chemical preparations of iron; see Vitriolate.

MASSICOT. A name given to the *yellow* oxide of lead, as minium is applied to the *red* oxide.

MATRASS. Another name for a bolt-head; which see.

MATRIX. The bed in which a metallic ore is found. See page 291.

MATT. That mass of metal which separates from the scoria in smelting ores without previous roasting.

MENSTRUUM. The fluid in which a *solid* body is dissolved. Thus water is a menstruum for salts, gums, &c. and spirit of wine for resins.

METALLIC OXIDES. Metals combined with oxygen. By this process they are generally reduced to a pulverulent form, are changed from combustible to incombustible substances; and receive the property of being soluble in acids. See page 285.

METALLURGY. The art of extracting and purifying metals. See page 282.

MINERAL. Any natural substance of a metallic, earthy, or saline nature, whether simple or compound, is deemed a mineral.

MINERALIZERS. Those substances which are combined with metals in their ores; such are sulphur, arsenic, oxygen, carbonic acid, &c. See page 292.

MINERALOGY. The science of fossils and minerals.

MINERAL WATERS. Waters which hold some metal, earth, or salt, in solution. They are frequently termed Medicinal Waters.

MINIUM. The red oxide of lead, commonly called red-lead. See note ‡, page 361.

MOLECULE. The molecules of bodies are those ultimate particles of matter which cannot be decomposed by any chemical means. See note *, page 249.

MOLYBDATES. Salts formed by the combination of any base with the molybdic acid. See page 194.

MORDANTS. Substances which have a chemical affinity for particular colours; they are employed by dyers as a bond to unite the colour with the cloth intended to be dyed. Alum is of this class.

MOTHER-WATERS, or MOTHERS. The liquors which are left after the crystallization of any salts. See page 235.

MUCILAGE. A glutinous matter obtained from vegetables, transparent and tasteless, soluble in water, but not in spirit of wine. It chiefly consists of carbon and hydrogen, with a little oxygen.

MUCITES. Salts formed by the combination of any base with the mucous acid. See page 201.

MUFFLE. A semi-cylindrical utensil, resembling the tilt of a boat, made of baked clay; its use is that of a cover to cupels in the assay furnace, to prevent the charcoal from falling upon the metal, or whatever is the subject of experiment.

MURIATES. Salts formed by the combination of any base with muriatic acid. See page 218.

N.

NATRON. One of the names for mineral alkali, or soda.

NEUTRALIZE. When two or more substances mutually disguise each other's properties, they are said to neutralize one another.

NEUTRAL SALT. A substance formed by the union of an acid with an alkali, an earth, or a metallic oxide, in such proportions as to saturate both the base and the acid.

NITRATES. Salts formed by the combination of any base with nitric acid. See page 222.

NITROGEN. A simple substance, by the French chemists called azote. It enters into a variety of compounds, and forms more than three parts in four of atmospheric air. See page 60.

O.

OCHRES. Various combinations of the earths with oxide, or carbonate, of iron.

OIL. A fluid substance well known. It is composed of hydrogen, oxygen, and carbon.

ORES. Metallic earths, which frequently contain several extraneous matters; such as sulphur, arsenic, &c.

OXALATES. Salts formed by the combination of any base with oxalic acid. See page 230.

OXIDE. Any substance combined with oxygen, in a proportion not sufficient to produce acidity.

OXIDIZE. To combine oxygen with a body without producing acidity.

OXIDIZEMENT. The operation by which any substance is combined with oxygen, in a degree not sufficient to produce acidity.

OXYGEN. A simple substance composing the *greatest* part of water, and part of atmospheric air. See pages 59 and 357.

——— *gas*. Oxygen converted to a gaseous state by caloric. It is also called vital air. It forms nearly one-fourth of atmospheric air.

OXYGENIZE. To acidify a substance by oxygen. Synonymous with Oxygenate; but the former is the better term.

OXYGENIZABLE. A term applicable to all bodies that combine with oxygen, and do not emit flame during the combination.

OXYGENIZEMENT. The production of acidity by oxygen. See page 171.

P.

PARTING. The operation of separating gold from silver by means of nitrous acid, and other mediums. See page 19.

PELICAN. A glass alembic, with a tubulated capital, from which two opposite and crooked arms pass out, and enter again at the swell of the vessel. The instrument is designed for operations of cohobation, and is calculated to save the trouble of frequently luting and unluting the apparatus. It is now seldom used.

PELLICLE. A thin skin which forms on the surface of saline solutions and other liquors, when boiled down to a certain strength.

PHLOGISTON. An old chemical name for an imaginary substance, supposed to be a combination of fire with some other matter, and a constituent part of all inflammable bodies, and of many other substances. See note, page 359.

PHOSPHATES. Salts formed by the combination of any base with phosphoric acid. See page 224.

PHOSPHITES. Salts formed by the combination of any base with phosphorous acid. See page 226.

PHOSPHURETS. Substances formed by an union with phosphorus. Thus we have phosphuret of lime, phosphuretted hydrogen, &c. See page 264.

PLUMBAGO. Carburet of iron, or the *black lead* of commerce. See page 273.

PNEUMATIC. Any thing relating to the airs and gases.

——————— *trough*. A vessel filled in part with water or mercury, for the purpose of collecting gases, so that they may be readily removed from one vessel to another. See the last note, page 56.

PRECIPITATE. Any matter which, having been dissolved in a fluid, falls to the bottom of the vessel on the addition of some other substance capable of producing a decomposition of the compound, in consequence of its attraction either for the menstruum, or for the matter which was before held in solution.

PRECIPITATION. That chemical process by which bodies dissolved, mixed, or suspended in a fluid, are separated from that fluid, and made to gravitate to the bottom of the vessel.

PRINCIPLES OF BODIES. Synonymous with *Elements*; which see.

PRUSSIATES. Salts formed by the combination of any base with prussic acid. See page 233.

PUTREFACTION. The last fermentative process of nature, by which organized bodies are decomposed so as to separate their principles, for the purpose of reuniting them by future attractions, in the production of new compositions.

PYRITES. An abundant mineral found on the English coasts, and elsewhere. Some are sulphurets of iron, and others sulphurets of copper, with a portion of alumine and silex. The former are worked for the sake of the sulphur, and the latter, for sulphur and copper. They are also called Marcasites and Fire-stone.

——————— *martial*. That species of pyrites which contains iron for its basis. See a full account of these minerals in Henckel's Pyritologia.

OMETER. An instrument invented by Mr. Wedgwood for ascertaining the degrees of heat in furnaces and intense fires. See Philosophical Transactions, vol. lxii. and lxiv. and Chemical Catech. note, page 81.

OPHORI. Compound substances which heat of themselves, and take fire on the admission of atmospheric air. See an account of a variety of experiments with these compositions in Wiegleb's Chemistry, quarto, page 622, &c.

Q.

RTATION. A term used by refiners in a certain operation of parting. See Lewis's Com. Tech. page 135.

RTZ. A name given to a variety of siliceous earths, mixed with a small portion of lime or alumine. Mr. Kirwan confines the term to the *purer* kind of silex. Rock crystal and the amethyst are species of quartz.

R.

ICALS. A chemical term for the *Elements* of bodies; which see.

——— *compound.* When the base of an acid is composed of two or more substances, it is said that the acid is

REFRACTORY. A term applied to earths or metals that are either infusible, or that require an extraordinary degree of heat to change or melt them.

REFRIGERATORY. A contrivance of any kind, which, by containing cold water, answers the purpose of condensing the vapour or gas that arises in distillation. A worm-tub is a refrigeratory.

REGISTERS. Openings in chimneys, or other parts of chemical furnaces, with sliding doors to regulate the quantity of atmospheric air admitted to the fire-place, or to open or shut the communication with the chimney at pleasure.

REGULUS. In its chemical acceptation, signifies a pure metallic substance, freed from all extraneous matters.

REPULSION. A principle whereby the particles of bodies are prevented from coming into actual contact. It is thought to be owing to *caloric*, which has been called the repulsive power. See chap. xiii. page 402.

RESIDUUM. What is left in a pot or retort after the more valuable part has been drawn off. Thus the sulphate of potass which remains in the pot after the distillation of nitrous acid is called the residuum. It is sometimes called the *caput mortuum*.

RESINS. Vegetable juices concreted by evaporation either spontaneously or by fire. Their characteristic is solubility in alcohol, and not in water. It seems that they owe their solidity chiefly to their union with oxygen.

RETORT. A vessel in the shape of a pear, with its neck bent downwards, used in distillation; the extremity of which neck fits into that of another bottle called a receiver.

REVERBERATORY. An oven or furnace in which the flame is confined by a dome which occasions it to be beat down upon the floor of the furnace before it passes into the chimney. Some are so contrived that it returns or reverberates upon the matter under operation.

REVIVIFICATION. See ***Reduction***, which is a synonymous term: though "revivification" is generally used when speaking of quicksilver.

ROASTING. A preparative operation in metallurgy to dissipate the sulphur, arsenic, &c. with which a metal may be combined.

ROCK-CRYSTAL. Crystallized silex. See page 117.

S.

SACCHOLATES. Salts formed by the combination of any base with saccholactic acid. See page 20[illegible]

FIABLE BASES. All the metals, alkalies, and earths, which are capable of combining with acids, and forming salts, are called salifiable bases.

NE. Partaking of the properties of a salt.

'S *neutral*. A class of substances formed by the combination to saturation of an acid with an alkali, an earth, or other salifiable base.

— *triple*. Salts formed by the combination of an acid with two bases or radicals. The tartrate of soda and potass (Rochelle salt) is an instance of this kind of combination.

) *bath.* } See *Bath.*
— *heat.* }

)IVER. A matter, composed of different salts, which rises as a pellicle on the surface of the pots in which glass is melted. It is used as a flux in the fusion of ores, and for other purposes. The term is probably a corruption of "Selle de verre."

COLOURS. A name given to various expressed vegetable juices of a viscid nature, which are inspissated by slow evaporation for the use of painters, &c.; sap-green, gamboge, &c. are of this class.

NACEOUS. A term applied to any substance which is of the nature or appearance of soap. See page 156.

URATION. The act of impregnating a fluid with another substance, till no more can be received or imbibed.

SOLUBILITY. A characteristic of most salts. See *Solution* See also page 239.

SOLUTION. The perfect union of a solid substance with a fluid. Salts dissolved in water are proper examples of solution.

SPARS. A name formerly given to various crystallized stones; such as the fluor spar, the adamantine spar, &c. These natural substances are now distinguished by names which denote the nature of each.

SPECIFIC GRAVITY. See the word *Gravity.*

SPELTER. The commercial name of *zinc.*

SPIRIT. A term used by the early chemists to denote all volatile fluids collected by distillation.

——— *proof.* A term made use of to describe such ardent spirits as are of the same strength as the brandy of commerce, or of the specific gravity of 0.930, water being 1.000.

STALACTITES. Certain concretions of calcareous earth found suspended like icicles in caverns. They are formed by the oozing of water, through the crevices, charged with this kind of earth. See note †, page 117.

STEATITES. A kind of stone composed of silex, iron, and magnesia. Also called French chalk, Spanish chalk, and soap-rock.

STRATIFICATION. A chemical operation by which bodies are placed in a condition to act mutually upon each other, by being arranged layer by layer, stratum super stratum, as is practised by metallurgi-ts.

SUB-SALTS. Salts with less acid than is sufficient to neutralize their radicals. See page 215.

SUBERATES. Salts formed by the combination of any base with the suberic acid. See page 232.

SUBLIMATE. A name given to several mercurial preparations.

SUBLIMATION. A process whereby certain volatile substances are raised by heat, and again condensed by cold into a solid form. Flowers of sulphur are made in this way. The soot of our common fires is a familiar instance of this process. See *Flowers.*

SUCCINATES. Salts formed by the combination of any base with the succinic acid. See page 202.

SUGAR. A well-known substance, found in a variety of vegetables, composed of oxygen, hydrogen, and carbon See page 274.

SULPHATES. Salts formed by the combination of any base with the sulphuric acid. See page 216.

SULPHITES. Salts formed by the combination of any base with the sulphurous acid. See page 218.

SULPHURES, or SULPHURETS. Combinations of alkalies, or metals with sulphur. See page 253.

SULPHURETTED. A substance is said to be sulphuretted when it is combined with sulphur. Thus we say Sulphuretted hydrogen, &c.

SUPER-SALTS. Salts with an excess of acid, as the supertartrate of potass. See page 215.

SYNTHESIS. When a body is examined by *dividing* it into its component parts, it is called analysis; but when we attempt to prove the nature of a substance by the *union* of its principles, the operation is called synthesis.

SYPHON. A bent tube used by chemists for drawing liquids from one vessel into another. It is sometimes called a *Crane*.

T.

TARTRATES. Salts formed by the combination of any base with the acid of tartar. See page 231.

TEMPERATURE. The absolute quantity of free caloric which is attached to any body occasions the degree of temperature of that body. See page 81.

TENACITY. Is a term used when speaking of glutinous bodies. It is also expressive of the adhesion of one substance to another.

TEST. That part of a cupel which is impregnated with litharge in the operation of refining lead. It is also the name of whatever is employed in chemical experiments to detect the several ingredients of any composition. See *Re-agent*.

TEST-PAPERS. Papers impregnated with certain chemical re-agents; such as litmus, turmeric, radish, &c. They are used to dip into fluids to ascertain by a change of colours the presence of acids and alkalies.

THERMOMETER. An instrument to show the relative heat of bodies. Fahrenheit's thermometer is that chiefly used in England. (See page 81.) Other thermometers are used in different parts of Europe. For the difference in the scale of these thermometers, see the Table at page 463.

TINCAL. The commercial name of crude borax.

TINCTURES. Solutions of substances in spirituous menstrua.

TORREFACTION. An operation similar to roasting; which see.

TRITORIUM. A vessel used for the separation of two fluids which are of different densities. The same operation may be performed by a common funnel.

TRITURATION. A chemical operation whereby substances are united by friction. Amalgams are made by this method.

TUBULATED. Retorts which have a hole at the top for inserting the materials to be operated upon without taking them out of the sand heat, are called *tubulated* retorts.

TUNGSTATES. Salts formed by the combination of any base with tungstic acid. See page 229.

TUTENAG. An Indian name for zinc. Chinese copper is also called by this name, which is a compound of copper, tin, and arsenic, much resembling silver in colour.

V.

VACUUM. A space unoccupied by matter. The term is generally applied to the exhaustion of atmospheric air by chemical or philosophical means.

VAPOUR. This term is used by chemists to denote such exhalations only as can be condensed and rendered liquid again at the ordinary atmospheric temperature, in opposition to those which are *permanently* elastic.

VATS. Large chemical vessels, generally of wood, for making infusions, &c.

VITAL AIR. Oxygen gas. The empyreal or fire-air of Scheele, and the dephlogisticated air of Priestley.

VITRIFICATION. When certain mixtures of solid substances, such as silex and an alkali, are exposed to an intense heat, so as to be fused, and become glass, they are then said to be vitrified, or to have undergone vitrification.

VITRIOLS. A class of substances, either earthy or metallic, which are combined with the vitriolic acid. Thus there is vitriol of lime, vitriol of iron, vitriol of copper, &c. These salts are now called Sulphates, because the acid which forms them is called sulphuric acid.

VITRIOLATED TARTAR. The old name for sulphate of potass.

VOLATILE ALKALI. Another name for ammonia.

VOLATILE SALTS. The commercial name for carbonate of ammonia. See page 164.

VOLATILITY. A property of some bodies which disposes them to assume the gaseous state. This property seems to be owing to their affinity for caloric.

VOLUME. A term made use of by modern chemists to express the space occupied by gaseous or other bodies.

U.

UNION *chemical.* When a mere mixture of two or more substances is made, they are said to be mechanically united; but when each or either substance forms a component part of the product, the substances have formed a *chemical* union.

ULATION. The roasting of ores, to separate the arsenic, sulphur, and whatever else is of a volatile nature that is connected with and mineralizes the metal. When the matter is preserved which flies off, the process is called sublimation; but when this matter is neglected, the operation is called ustulation.

W.

ER. The most common of all fluids, composed of 85 parts of oxygen and 15 of hydrogen. See page 96.

—— *mineral.* Waters which are impregnated with mineral and other substances are known by this appellation. These minerals are generally held in solution by carbonic, sulphuric, or muriatic acid.

dry. A term used by chemical writers when treating of analysis or decomposition. By decomposing in the dry way, is meant, by the agency of fire.

humid. A term used in the same manner as the foregoing, but expressive of decomposition in a fluid state, or by means of water, and chemical re-agents, or tests.

DING HEAT. That degree of heat in which two pieces of iron or of platina may be united by hammering.

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